SOLID STATE ABSTRACTS

A reference journal devoted to the theory, production and use of solid state materials and devices

VOLUME 5 NUMBERS 3 – 4

PHYSICS

METALLURGY

ELECTRONICS

SEMICONDUCTORS

PHOSPHORS

MAGNETICS

DIELECTRICS

SUPERCONDUCTORS

METALS

SOLID STATE ABSTRACTS

VOLUME 5, NUMBERS 3-4

MARCH - APRIL 1964

Abstracts 23,516–24,857

TABLE OF CONTENTS

Abstracts of the Solid State Literature

METALLURGY AND CHEMISTRY OF SOLIDS

GENERAL . . . 101
THERMODYNAMIC PROPERTIES OF ELEMENTS AND ALLOYS . . . 101
CRYSTAL STRUCTURE . . . 104
General . . . 104
Crystal Imperfections . . . 109
Point Defects (Vacancies and Interstitials) . . . 110
Dislocations . . . 113
Stacking Faults, Twins, etc. . . . 116
Impurities . . . 119
CRYSTAL GROWTH . . . 122
General . . . 122
Semiconductor Crystals . . . 124
Metal Crystals . . . 125
Other Crystals . . . 126
CRYSTAL SURFACES . . . 127
ENVIRONMENTAL EFFECTS . . . 128

SOLID STATE PHYSICS

GENERAL . . . 129
CRYSTAL PHYSICS . . . 129
Energy Band Structure . . . 129
Lattice Vibrations . . . 131
Electronic Structure . . . 132
ELECTRICAL PROPERTIES . . . 132
Nuclear Quadrupole Effects . . . 132
Dielectric Properties . . . 133
Carrier Properties . . . 136
General . . . 136
Recombination (Lifetime) . . . 136
Effective Mass and Charge . . . 137
Transport . . . 138
Resistivity (Conductivity) . . . 139
Superconductivity . . . 143
Breakdown . . . 146
Magnetoelectric (Galvanomagnetic) Properties . . . 146
General . . . 146
Magnetoresistivity . . . 147
Hall Effect . . . 148
Cyclotron Resonance . . . 148
Electrical Properties of Surfaces . . . 149
Other Electrical Properties . . . 150
MAGNETIC PROPERTIES . . . 150
General . . . 150
Magnetic Susceptibility . . . 150
Magnetic Structure . . . 151
Magnetostriction, Magnetoelasticity, and Piezomagnetism . . . 153
Ferro- and Ferrimagnetism . . . 154
General . . . 154
Theory . . . 156
Magnetization . . . 158
Structural Properties . . . 162
Ferro- and Ferrimagnetic Resonance . . . 163
Antiferro- and Antiferrimagnetism . . . 166
Antiferro- and Antiferrimagnetic Resonance . . . 167
Paramagnetism . . . 168
Paramagnetic Resonance . . . 169
Diamagnetism . . . 174
OPTICAL PROPERTIES . . . 174
General . . . 174
Absorption (Transmission) . . . 175
Radiation and Luminescence . . . 178
Photoelectronic Properties . . . 182
Other Optical Properties . . . 184
Optical Constants . . . 184
Reflectivity (Reflectance) . . . 184
Refraction . . . 185
Polarization (Faraday) Effects . . . 185
Optical Modulation . . . 186
THERMAL PROPERTIES . . . 186
Specific Heat . . . 186
Thermal Conductivity . . . 188
Thermal Expansion . . . 189
Thermoelectric and Thermomagnetic Properties . . . 189
MECHANICAL PROPERTIES . . . 190
Deformation Properties . . . 190
Sonic and Ultrasonic Properties . . . 193
Internal Friction . . . 194

SOLID STATE DEVICES

DIODES . . . 195
TRANSISTORS . . . 196
OPTICAL DEVICES . . . 199
Photoelectric Devices . . . 199
Optical Modulators . . . 199
MASERS AND LASERS
Characteristics . . . 200
Associated Devices . . . 204
Applications . . . 205

BASIC SOLID STATE DEVICE CIRCUITS

GENERAL . . . 205
Network Theory . . . 205
Microcircuits . . . 206
Circuit Aspects of Devices . . . 206
AMPLIFIERS . . . 207
OSCILLATORS . . . 209
SWITCHING CIRCUITS . . . 210
SIGNAL CONVERTERS . . . 211
PULSE CIRCUITS . . . 211
OTHER CIRCUITS . . . 212

APPLICATIONS OF SOLID STATE DEVICES

COMMUNICATIONS TYPE APPLICATIONS . . . 213
COMPUTERS and OTHER DATA HANDLING SYSTEMS . . . 214
Digital Computers . . . 214
Analog Computers and Other Data Systems . . . 216
POWER and CONTROL APPLICATIONS . . . 216
INSTRUMENTATION . . . 217
OTHER APPLICATIONS . . . 219

SUBJECT INDEX . . . 220

AUTHOR INDEX . . . 243

PUBLISHED BY

Cambridge Communications Corporation, 238 Main Street, Cambridge, Massachusetts 02142 Tel. 491-0710

Subscription Rate: U.S.A. and Canada — $96. per year — Special 3 year rate — $273.
Foreign — $106. per year — Special 3 year rate — $303

Copyright 1964 by Cambridge Communications Corp. Printed in the U.S.A.

ABSTRACTS OF THE SOLID STATE LITERATURE

METALLURGY AND CHEMISTRY OF SOLIDS

GENERAL

23,516 RHENIUM by K.B. Lebedev; Feb. 25, 1964, Transl. from the monograph "Reniy" Moscow. Metallurgizdat, 1963, pp. 1-208; STAR, Vol. 2, p. 863(A), Apr. 8, 1964 JPRS-23361; OTS-64-21632; OTS $3.50

This book presents information on the properties, applications, sources, production methods, and analytical chemistry of rhenium. It is intended for engineering and scientific workers in the fields of geology, metallurgy, and chemistry of the rare and less-common elements.

23,517 "BORON" by A.G. Massey; Scientific Am., Vol. 210, pp. 88-97, Jan. 1964

Useful properties of boron and the many recent applications of its compounds are discussed. The importance of appropriate boron compounds in the fields of high energy fuel development, synthetic chemistry, neutron shielding material research, high temperature lubricant development, and boron based polymer synthesis are outlined.

23,518 BETA-SILICON CARBIDE AND ITS POTENTIAL FOR DEVICES by W. E. Nelson, F.A. Halden and A. Rosengreen (Stanford Res. Inst.); Final Rept. No. 21, Dec. 31, 1963, 43 pp., Contract NObsr87235; U.S. Gov. Res. Rep., Vol. 39, p. 32(A), Apr. 20, 1964 AD 428 005 OTS $4.60

23,519 ZINC SULFIDE, DATA SHEETS by M. Neuberger and D.L. Grigsby (Electronic Prop. Infor. Ctr.); Rept. No. DS135, Dec. 1963, 72 pp., Contract AF33 616 8438, Proj. 7381; U.S. Gov. Res. Rep., Vol. 39, p. 37(A), Apr. 5, 1964 AD 427 288 OTS $7.60

THERMODYNAMIC PROPERTIES of ELEMENTS and ALLOYS

23,520 AN ANALYTIC FORMULATION OF EQUATIONS OF STATE by D.J. McCloskey (RAND); Rept. No. RM3905PR, Feb. 1964, 73 pp., Contract AF 49 638 700; U.S. Gov. Res. Rep., Vol. 39, p. 134(A), Apr. 20, 1964 AD 429 196 OTS $8.60

A general equation of state is presented that provides a suitable description of the thermodynamic behavior of metals over a very wide range of temperature and compression. The thermodynamic dependence of pressure and specific internal energy upon temperature and compression is described by equations having coefficients that can be related to measured or calculated physical variables. This makes such a formulation useful in assaying the effect of the parametric variation of the equation of state on hydrodynamic calculations. A description of the physical basis of the terms in the equation of state is given. The calculation of the specific entropy is reviewed and a method of calculation of Hugoniot points is presented. A summary of the program that has been written for machine calculation of the equation of state is given, along with the appropriate input instructions.

23,521 THEORETICAL EQUATION OF STATE FOR FACE CENTERED CUBIC METALS by D.J. Pastine (Naval Ord. Lab.); NOL TR63 108, Aug. 7, 1963, 27 pp.; U.S. Gov. Res. Rep., Vol. 39, p. 58(A), Apr. 5, 1964

AD 427 081 OTS $3.60

A Morse function is used as the form of the volume dependent energy term in the expression for the Helmholtz free energy of a Debye solid. The consequent form of the Mie-Gruneisen equation of state is then obtained using an adjusted form of the Slater relation for the Gruneisen parameter. Theoretical Hugoniots are calculated for Al, Cu, and Ag and found to agree well with experimental Hugoniots over a broad pressure range.

23,522 THERMODYNAMIC STUDY OF GERMANIUM MONOTELLURIDE USING A MASS SPECTROMETER by R. Colin and J. Drowart (U. Libre de Bruxelles); J. Phys. Chem., Vol. 68, pp. 428-430(L), Feb. 1964

The vaporization of GeTe was found to be represented by the reaction $GeTe(s) \rightarrow GeTe(g)$; secondary reactions involve $GeTe(s) \rightarrow Ge(s) + Te_2(g)$ and $2GeTe(s) \rightarrow Ge(s) + GeTe_2(g)$. Partial pressures of decomposition products of GeTe at different temperatures are reported. Values of enthalpies for the above reactions are 48.6 ± 2.1, 25.8 ± 2.2 and 55.8 ± 3.0 kcal/mole at 298°K. Additional data obtained are:

(i) Heat of Formation ($\Delta H°_{298}$) of GeTe(s) = 6.0 ± 2.3 kcal/mole
(ii) Dissociation Energy ($D°_{298}$) of GeTe(g) = 93.5 ± 2.0 kcal/mole
(iii) Heat of Atomization of $GeTe_2$ = 138.3 ± 3.0 kcal/mole

Comparison of obtained data with those of other researchers for IV-VI compounds shows that the electronically excited E-states in these compounds are analogous.

23,523 HEATS OF FORMATION OF PHOSPHORUS OXIDES by E.P. Egans, Jr. and B.B. Luff (Tennessee Valley Authority); Prog. Rept. June 1 - Nov. 30, 1963, 44 pp.; U.S. Gov. Res. Rep., Vol. 39, p. 131(A), Apr. 20, 1964 AD 429 008 OTS $4.60

23,524 THE THERMODYNAMIC AND PHYSICAL PROPERTIES OF BERYLLIUM COMPOUNDS. Part V. HEAT OF FORMATION AND ENTROPY OF BERYLLIUM (I) CHLORIDE (g) by M.A. Greenbaum, M.L. Arin, M. Wong and M. Farber (Rocket Power Res. Labs.); J. Phys. Chem., Vol. 68, pp. 791-795, Apr. 1964

The equilibrium $BeCl_2(g) + Be(I) = 2BeCl(g)$ has been studied over the temperature range 1573-1723°K by the molecular flow effusion technique in order to obtain the heat of formation and entropy for BeCl(g). Over this temperature range ΔH_r was found to be 89.1 ± 7.6 kcal/mole and ΔS_r was 39.4 ± 4.6 cal/deg/mole. From recent experimental data and available thermal functions, the second law $\Delta H_{f,298}$ for BeCl(g) was $+3.7 \pm 3.8$ kcal/mole, which compared favorably with the corresponding third law value of $+2.0 \pm 0.8$ kcal/mole. The experimental value for $S°_{298}$ for BeCl(g) was found to be 53.0 ± 2.3 cal/deg/mole.

23,525 THE HEAT OF FORMATION OF GERMANIUM DIOXIDE by J.L. Bills and F.A. Cotton (MIT); J. Phys. Chem., Vol. 68, pp. 802-806, Apr. 1964

A new procedure has been used to measure the standard enthalpy of formation of hexagonal germanium (IV) oxide, GeO_2(c, I), affording the value -132.2 ± 1.2 kcal/mole. This agrees very well with the result obtained by Yokokawa, et al. (-132.3 ± 1.0), and one which can be calculated from the data of Jolly and Latimer (-132.6 ± 2.0), but differs by 3.9 kcal/mole from the value, based on combustion data, listed in the National Bureau of Standards Tables (-128.3 kcal/mole.

23,526 THERMODYNAMIC PROPERTIES OF SOLID SOLUTIONS WITH SPINEL-TYPE STRUCTURE. Part I. THE SYSTEM Co_3O_4-Mn_3O_4 by E. Aukrust and A. Muan (Pennsylvania State U.); Trans. Met. Soc. AIME, Vol. 230, pp. 378-382, Apr. 1964

Activity-composition curves for cobalt oxide and manganese oxide in $(Co, Mn)_3O_4$ solid solutions with spinel-type structure have been determined by studying the equilibrium between the spinel phase and a coexisting (Co, Mn)O solid solution phase in the temperature range 1100° to 1400°C. Within limits

of experimental error, the system displays the behavior of a regular solution. The excess integral free energy of mixing is represented by the equation $\Delta F^{Ex} = -5520\, N_{Co} \cdot N_{Mn}$. The standard free energy of formation of cobalt manganite, $CoMn_2O_4$, from the oxide components CoO and Mn_2O_3 at 1200°C is calculated to be -8.6 kcal.

23,527 THE FREE ENERGIES OF FORMATION OF THE VANADIUM, NIOBIUM, AND TANTALUM CARBIDES by W.L. Worell and J. Chipman (MIT); J. Phys. Chem., Vol. 68, pp. 860-866, Apr. 1964

By measuring the pressure of carbon monoxide in equilibrium with graphite-carbide-oxide mixtures at temperatures of 1180 to 1370°K, the free energies of formation of the carbon-rich carbides $V\overline{C}$, $Nb\overline{C}$, and $Ta\overline{C}$ have been determined. The notations $M\overline{C}$ and $\overline{M}C$ are introduced to denote carbide compositions, respectively, at the carbon-rich and at the metal-rich boundaries of the homogeneous field. The thermodynamic properties of other group VA carbides ($\overline{M}C$ and M_2C) are estimated from the $M\overline{C}$ data and the phase diagrams.

Melting of Ce - See 23,719

23,528 PARTIAL PRESSURES IN EQUILIBRIUM WITH GROUP IV TELLURIDES. Part III. GeTe by R.F. Brebrick and A.J. Strauss (Lincoln Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 293(A), Mar. 1964

Partial pressures of GeTe(g) and Te_2(g) in equilibrium with Ge- and Te-saturated GeTe(c) and with Te-saturated Ge(c) have been determined as a function of temperature by measuring the optical absorption of the vapor. Between 500° and 725°C, the maximum melting point of GeTe(c), the partial pressure of GeTe(g) over both Ge- and Te-saturated GeTe(c) is given by $\log p_{GeTe}(\text{Torr}) = -(10.1 \times 10^3)/T + 8.84$. The maximum value pf p_{Te_2} in equilibrium with GeTe(c) is 2.5±0.2 Torr, the partial pressure over Te-saturated GeTe(c) between 644° and 679°C. This value is about 20 times greater than p_{Te_2} in equilibrium with Ge-saturated GeTe(c) over the same temperature range. At the maximum melting point of GeTe(c), p_{GeTe} = 17 Torr and $p_{Te_2} = 0.6 \pm 0.3$ Torr. The maximum partial pressures in equilibrium with Te-saturated Ge(c) are reached at 890°C, where p_{GeTe} = 125 Torr and p_{Te_2} = 2.2 Torr.

23,529 MASS SPECTROMETRIC STUDY OF THE NONSTOICHIOMETRIC VAPORIZATION OF CADMIUM ARSENIDE by J.B. Westmore, K.H. Mann and A.W. Tickner (Natl. Res. Council, Ottawa); J. Phys. Chem., Vol. 68, pp. 606-612, Mar. 1964

Cd_3As_2 is shown to dissociate thermally in the temperature range 220 to 280° according to the reaction $Cd_3As_2(s) \rightleftharpoons 3Cd(g) + 0.5As_4(g)$. The variation of the partial pressures with temperature was measured and an energy barrier was found to exist for the vaporization of arsenic with the result that the vapor is nonstoichiometric. For cadmium, the experimental data may be represented by $\log P_{Cd} = -8083/T + \text{constant}$. The heat of dissociation, ΔH_{298}, is found to be 112.0±1.5 kcal/mole, and the heat of formation of Cd_3As_2 is calculated as 14.5±3.0 kcal/mole. Separate experiments with arsenic give a heat of activation of sublimation of 43.0 ± 0.4 kcal/mole of As_4.

23,530 THERMODYNAMICS OF ALLOYS: TIN-SOLUTION CALORIMETRY STUDIES OF LIQUID TIN-SILVER ALLOYS AND OF RARE EARTH MATERIALS by J.N. Pratt and A.W.H. Morris (Birmingham U., Gt. Brit.); Final Tech. Rept., Nov. 20, 1963, 1 v., Contract DA91 591EUC2729; U.S. Gov. Res. Rep., Vol. 39, p. 108(A), Apr. 20, 1964 AD 429 007 OTS $3.60

A tin-solution calorimeter was employed for the measurement of enthalpies of solution and formation of various alloys. Using a technique permitting the direct measurement of the partial quantities for each component, detailed values were obtained for the heats of solution of tin in a range of liquid silver-tin alloys; some corresponding values for the silver partial and for the integral quantities have also been obtained. Studies of the heats of solution of rare earth materials in liquid tin continued. New measurements were made with ytterbium and praseodymium, and earlier values for cerium and lanthanum were recalculated in the light of more recent specific heat data.

23,531 HEATS OF SOLUTION OF THE GROUP III ELEMENTS ALUMINUM, GALLIUM, AND INDIUM IN LIQUID TIN AT 750°K by M. Pool and C. Lundin (U. Denver); Trans. Met. Soc. AIME, Vol. 230, pp. 589-591, Apr. 1964

The relative partial molar enthalpies of aluminum, gellium, and indium in liquid tin have been measured at 750°K by liquid-metal solution calorimetry. The relative partial molar heats of solution of aluminum in liquid and dilute Al-Sn liquid solutions are large and positive whereas the partial molar heat of solution of indium in liquid tin is small and negative. The value of the partial molar heat of solution of gallium at infinite dilution is 765 cal/g-atom. Concentration dependence of the partial molar heat of solution for aluminum is interpreted by quasi-chemical statistical models. The theory of Oriani and Murphy is found to predict the correct compositional dependence over the range investigated.

23,532 GUINIER-PRESTON ZONES IN AN ALUMINIUM-SILVER ALLOY by A. Kelly and R.B. Nicholson (U. Cambridge, England); Acta Met., Vol. 12, p. 277(L), Feb. 1964

This note is a comment on an earlier paper concerning reconciliation of X-ray and electron microscopic data of Guinier-Preston zones in aluminum-silver alloy. The discrepancy between data from two sources is lessened when the X-ray curve is interpreted in terms of a range of zone sizes. Relative advantages of these two techniques in determining particle size are pointed out.

23,533 ON GUINIER-PRESTON ZONES IN AN ALUMINIUM-SILVER ALLOY by S. Weissmann (Rutgers U.) and D.F. Wriedt (U.S. Steel); Acta Met., Vol. 12, pp. 276-277(L), Feb. 1964

A critical graphical analysis of the X-ray scattering data from Guinier-Preston zones in an aluminum-silver alloys has been made to examine the possibility of reconciling particle size results from X-ray data with those obtained from electron microscopy. Better agreement between X-ray and electron microscopy results is expected in the size range of 20A-50A.

23,534 VARIATIONS WITH PRESSURE OF NICKEL-CARBON EUTECTIC MELTING POINTS AND COMPOSITION by H.M. Strong (GE Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 398(A), Apr. 1964

The variations with pressure of the solubility of carbon in molten nickel and of their eutectic melting points have been observed to about 60 kbar. The eutectic composition increases in carbon concentration from 2.0-2.2 wt per cent at 1 atm. pressure to about 3.3 per cent at 60 kbar, while the melting point passes through a maximum of 1339 ± 3°C at 35 kbar, after which it decreases to 1334 ± 3° at 60 kbar. These temperatures were measured by a platinum-platinum 10 per cent rhodium thermocouple and are subject to revision for the influence of pressure on the thermal EMF of these materials. A comparison with chromel-alumel temperature readings to 1200°C at 52 kbar indicated that a chromel-alumel thermocouple, if it were stable at higher temperatures, would have indicated melting points about 30° higher. Evidence for nickel carbide formation under pressure was found. Graphite crystals precipitating from carbon solutions in nickel under pressure were spheroidal when diamond was the source of carbon and both spheroidal and flake- or kish-type with graphite as the carbon source. In the latter instance, increase of pressure favored the formation of spheroidal graphite.

23,535 SOLID SOLUTIONS OF CdTe AND InTe IN PbTe AND SnTe. Part I. CRYSTAL CHEMISTRY by A.J. Rosenberg, R. Grierson (Tyco Labs.), J.C. Woolley (U. Ottawa, Canada) and P. Nikolic (U. Belgrade, Yugoslavia); Trans. Met. Soc. AIME, Vol. 230, pp. 342-350, Mar. 1964

Extensive solid solubilities of CdTe (zincblende-type structure) and InTe (B37 type) in each of the rock salt-type compounds, PbTe and SnTe, have been observed. Partial phase diagrams have been determined by thermal analysis and X-ray metallography. The limiting mol fraction, X_m, of the solute in the rock salt-type a phase and the corresponding eutectic temperatures, T_e, are:

$(PbTe)_{1-x}(CdTe)_x$: $X_m \sim 0.2$, T_e = 866°C;
$(PbTe)_{1-x}(InTe)_x$: $X_m \sim 0.35$, T_e = 646°C;
$(SnTe)_{1-x}(CdTe)_x$: $X_m \sim 0.11$, T_e = 784°C;
$(SnTe)_{1-x}(InTe)_x$: $X_m \sim 0.53$, T_e = 630°C.

The lattice parameters of the a phase decrease linearly with X, even in $(PbTe)_{1-x}(CdTe)_x$, where a_0 (CdTe) = 6.481 A > a_0 (PbTe) = 6.459 A. This is taken as proof that the cadmium atom enters an octahedral interstice of the tellurium atom sublattice; i.e., the formation of the a-phase entails the direct replacement of lead by cadmium. The a_0 vs X curve extrapolates to 6.16A at X = 1, in agreement with the value predicted for an ionic crystal of CdTe; it is also consistent with the reported lattice parameter.

Solubility of:
Zn in GaAs and GaP - See 23,740
Ag in GaAs - See 23,714

23,536 DISTRIBUTION OF LEAD BETWEEN PHASES IN THE SILVER-ANTIMONY-TELLURIUM SYSTEM by R.A. Burmeister, R. McFarland and D.A. Stevenson (Stanford U.); Trans. Met. Soc. AIME, Vol. 230, pp. 473-476, Apr. 1964

The distribution of lead between phases in the Ag-Sb-Te system has been studied using microautoradiography. Two compositions were investigated, both containing an intermediate phase known as silver antimony telluride as the major phase, and one containing Ag_2Te and the other Sb_2Te_3 as the minor phase. For both compositions, two thermal treatments were used; nonequilibrium solidification from the melt and long equilibration anneals of the as-solidified structure. For each composition, lead was segregated in the minor phase of the as-solidified structure, but was distributed in the matrix after anneal. The electrical resistivity and carrier type were insensitive to the distribution of lead in the two-phase structure.

23,537 SOLUTE DISTRIBUTION AND EUTECTIC FORMATION IN AS-CAST NICKEL-BASE SUPERALLOYS by R. Gregg and B. Piearcey (Pratt and Whitney); Trans. Met. Soc. AIME, Vol. 230, pp. 599-600, Apr. 1964

Nickel-base superalloys in the as-cast condition exhibit a massive "white-etching" constituent in the interdendritic regions. In alloy SM200, this constituent is spherulitic, is situated between cored dendrite arms and is nucleated at the surface of dendrites. Electron microprobe analysis indicates the constituent to be an intermetallic-rich eutectic based on the binary eutectic Ni + Ni_3Al. Heat treatment of SM200 has revealed that the eutectic can be completely dissolved; the solid solution phase is not completely saturated and the eutectic is not a completely stable constituent of the alloy composition.

Distribution Coefficient of Zn in GaAs and GaP - See 23,740

Segregation in Spherulitic Crystalization - See 23,760 and 23,761

23,538 COMPOUNDS IN THE BINARY PHASE DIAGRAMS OF THE MONOVALENT CHLORIDES WITH THE MULTIVALENT CHLORIDES by R. Gut, E. Peterson and D.M. Gruen (Argonne Natl. Lab.); Nov. 1963, 23 pp., Contract W-31-109-eng-38, ANL-6803; STAR, Vol. 2, p. 868(A), Apr. 8, 1964

The phase-diagram literature has been surveyed to the end of 1960. Information about the binary systems of monovalent with multivalent chlorides was observed. Compounds of double chlorides occurring in these systems are listed in tabular form together with the available structural information.

23,539 THE EQUILIBRIUM PHASES IN THE URANIUM-ALUMINUM-IRON ALLOYS IN THE PARTIAL DOMAIN URANIUM-UAl_2-UFe_2 (Mallinckrodt Chem. Works); Dec. 30, 1963, 18 pp., Contract W-14-108-eng-8, MCW-TR-; STAR, Vol. 2, p. 453(A), Feb. 23, 1964

The ternary system uranium-aluminum-iron has been investigated. The phase relations were determined in the uranium-rich portion up to the quasi-binary section UFe_2-UAl_2. The results obtained were based on investigations by thermoanalysis, chemical and X-ray methods, and microscopy. The extended three phase equilibrium is typical for the system in the solid state. Uranium solutions showed a limited ternary solubility, but not the intermetallic compounds UAl_2, $U(Fe,Al)_2$, UFe_2, UFe. Tables are presented on the distribution of the liquid surfaces in the system U-UAl_2-UFe_2, and the extent of the four-phase liquid equilibrium in the system U-UAl_2-UFe_2. Phase diagrams surrounding the ternary system U-UAl_2-UFe_2 are also included.

23,540 INVESTIGATION OF THE TERNARY SYSTEMS NIOBIUM-TUNGSTEN-ZIRCONIUM AND NIOBIUM-MOLYBDENUM-ZIRCONIUM by Ye.M. Savitskiy and A.M. Zakharov, Jan. 3, 1964, 14 pp., Trans. from Issled Splavov Tsvetn. Metal., Akad. Nauk SSSR, No. 4, pp. 108-116, 1963; STAR, Vol. 2, p. 310(A), Feb. 8, 1964 JPRS-22593: OTS-64-21201, $.50

Polythermal sections of the ternary systems Nb-W-Zr and Nb-Mo-Zr (with ratios W:Zr = 4:1, 1:1, 1:3 and Mo:Zr = 2.1:1, 1:1, 1:3) have been studied by the methods of microscopic investigation, determination of the melting point and the microhardness, and X-ray diffraction. Projections of the polythermal diagrams onto the plane of the concentration triangle as well as isothermal section, at the temperatures 2000°, 1800°, and 100°C, were constructed. It was shown that the ternary systems Nb-W-Zr and Nb-Mo-Zr possess similar structures within the investigated temperature range. Also, it was established that the mutual solubility of W with Zr and Mo with Zr in Nb, in the solid state, is limited and is greatly reduced when the temperature is lowered.

23,541 THE PHASE DIAGRAM OF THE ALUMINIUM-MOLYBDENUM SYSTEM by L.K. Walford (Cavendish Lab.); Phil. Mag., Vol. 9, pp. 513-516, Mar. 1964

Some changes in the aluminum-rich end of the Al-Mo phase diagram are proposed. The results of several workers indicate that two new phases ($MoAl_4$ and $MoAl_6$) have to be introduced and that one phase ($MoAl_2$) should be omitted from the existing diagram.

23,542 THE OSMIUM-IRIDIUM EQUILIBRIUM DIAGRAM by R.D. Reiswig and J.M. Dickinson (Los Alamos Sci. Lab.); Trans. Met. Soc. AIME, Vol. 230, pp. 469-472, Apr. 1964

The Os-Ir equilibrium diagram has been determined. The diagram is of the simple peritectic type, with a peritectic temperature of about 2660°C. The solid miscibility gap is narrower than previously reported, the nearly vertical solvus lines occurring at about 42 and 63 wt pct Os. Widmanstaetten figures resembling martensite in some of the two-phase alloys account for a previously suspected transformation.

23,543 AN INVESTIGATION OF THE COPPER-RICH PORTION OF THE COPPER-ZIRCONIUM PHASE DIAGRAM BY ELECTRON-PROBE MICROANALYSIS by M. Donachie, Jr. (Chase Brass and Copper); J. Inst. Metals, Vol. 92,

Alloys have been prepared in order to investigate the extent of solid solubility of Zr in Cu and to determine the composition of the first intermediate phase. Electron probe microanalysis was supplemented by metallographic and thermal analysis. Results of four alloys containing > 16.4 per cent Zr indicate that Cu_4Zr is the first intermediate phase, alghough a range of solubility is associated with it. Maximum solubility observed by probe analysis is 0.17 per cent Zr. Thermal analysis indicated a eutectic temperature of ~ 970°C with with average eutectic composition ~ 13.5 per cent Zr.

23,544 ON THE SYSTEM NIOBIUM PENTOXIDE-TANTALUM PENTOXIDE by G. Mohanty, L. Fiegel and J. Healy (A.O. Smith); J. Phys. Chem., Vol. 68, pp. 208-210(L), Jan. 1964

Binary oxide samples have been pressed and sintered at appropriate temperatures and times to assure equilibrium. The Nb_2O_5-Ta_2O_5 phase diagram was determined with these samples using a high temperature diffractometer. Results in general agree with the equilibrium diagram of Holtzberg and Reisman, although limited solubility is found for the compound $2Nb_2O_5 \cdot Ta_2O_5$. The eutectoid transformation temperature for $2Nb_2O_5 \cdot Ta_2O_5 \rightarrow \alpha\text{-}Nb_2O_5 + \beta\text{-}Ta_2O_5$ is lower, occurring between 1350-1400°C. The two phase region ($\alpha\text{-}Ta_2O_{5ss} + \beta\text{-}Ta_2O_{5ss}$) was more accurately determined than previously.

23,545 X-RAY DIFFRACTION EVIDENCE FOR A CRITICAL END POINT FOR CERIUM I AND CERIUM II by B.L. Davis and L.H. Adams (U. California, Los Angeles); J. Phys. Chem. Solids, Vol. 25, pp. 379-388, Apr. 1964

A beryllium pressure vessel has been used to investigate the two face-centered phases of cerium at various temperatures and pressures along the phase boundary. X-ray diffraction records of the strong 111 peak of both phases show that the two peaks coalesce with increasing temperature and pressure along the boundary. The P-t region for the critical end point of the boundary is obtained by extrapolation of the change in d-spacing with distance along the boundary, and is found to be 350-400°C and 20-22 kb. The X-ray data also show that the compressibility and thermal expansion of the high-pressure (II) phase are greater than those of the low-pressure (I) phase. Rate studies indicate that under pressure phase I persists into the phase II stability field with lowering temperature. Considerable overstepping of pressure into this field is also possible before complete transformation of I-II will take place.

23,546 ELECTRICAL RESISTANCE OF BARIUM AT ELEVATED PRESSURE AND TEMPERATURE by B.C. Deaton and D.E. Bowen (Genl. Dynamics); Appl. Phys. Lett., Vol. 4, pp. 97-99(L), Mar. 15, 1964

Measurements of the electrical resistance of barium wires at pressures up to 67 kb and temperatures to 800°C are reported. The melting curve of the phase diagram determined from these measurements agrees with that of Jayaraman et al, but the BaI (bcc)-Ba II (hcp) transition line exhibits a pronounced negative slope while that determined by Jayaraman et al by differential thermal analysis has a positive slope. The triple point was observed at about 35 kb and 700°C, approximately where the fusion curve of Jayaraman et al shows a slight break in slope. A consequence of the negative slopes of the transition line and the fusion curve is that the fusion curve above about 35 kb is that of the hcp structure and the fusion curve would cross the room-temperature line in the vicinity of 140 kb. This and the similarity between the resistance melting curves observed at low pressures in the present work and those obtained at higher pressures suggest that the resistance transition near 144 kb and 25°C corresponds to melting

23,547 MISCIBILITY GAP IN THE CaO-SiO_2-Cr_2O_3 SYSTEM AT 1600°C by J.H. Swisher and C.L. McCabe (NASA); Trans. Met. Soc. AIME, Vol. 230, pp. 261-263(L), Feb. 1964

An experimental study of the tie line position in the two phase region arising from the existence of a miscibility gap at 1600°C in the CaO-SiO_2-Cr_2O_3 system is described. A partial phase diagram has been provided to indicate the shape and extent of the miscibility gap field. Results of this investigation differ greatly from those of earlier studies. Instances of usefulness of the present results in the extractive metallurgy field are pointed out.

23,548 THERMODYNAMIC STUDIES OF TERNARY LIQUID METALLIC SYSTEMS CONTAINING MISCIBILITY GAPS. Part I. THE ALUMINUM-BISMUTH-LEAD SYSTEM by T.C. Wilder and J.F. Elliott (MIT); J. Electrochem. Soc., Vol. 111, pp. 352-362, Mar. 1964

The partial and integral molar thermodynamic properties of the liquid Al-Bi-Pb system have been determined by EMF measurements of the reversible concentration cell

$$Al(liq) \mid Al^{3+}\ (AlCl_3 \text{ in } KCl \cdot NaCl) \mid \underline{Al}\ (\text{in Bi, Pb, or Bi-Pb})(liq)$$

in the range 700°-1000°C and distribution measurements of the two-phase alloys at 900°C. The measured properties of this system have been compared with estimates based on several theoretical treatments contained in the literature. The partial and integral molar properties of mixing, i.e., F_i^M, S_i^M, H_i^M, F^M, H^M, and S^M, in this system have higher positive deviations from ideality than the theoretical treatments would indicate. The miscibility gaps of 900°C

of the Al-Pb and Al-Bi systems are not as wide as those reported previously in the literature.

23,549 HIGH PRESSURE TRANSITION IN InSb by R.E. Hanneman and M.D. Banus (MIT); J. Phys. Chem. Solids, Vol. 25, pp. 293-302, Mar. 1964

InSb (phase I) transforms at room temperature under a pressure of 23 kbars to a metallic phase (II) having a body-centered tetragonal structure with lattice constants a = 5.79 ± 0.03 and c = 3.15 ± 0.03 A. An additional transition $InSb_{I \rightarrow IA}$ was observed and was attributed to a higher order electronic transition. The InSb pressure-temperature phase diagram is discussed on a thermodynamic basis. The electrical behavior of phase II and the kinetics of the $InSb_{I \rightleftharpoons II}$ transformations were investigated and compared to the $Sn_{\alpha \rightleftharpoons \beta}$ transformations. Approximate activation energies for the I→II and II→I reactions are reported and discussed in terms of various transformation mechanisms.

23,550 PHASE TRANSITIONS IN THE SYSTEM TUNGSTEN-CARBON by G. W. Orton (USAF Academy); Trans. Met. Soc. AIME, Vol. 230, pp. 600-602, Apr. 1964

Studies of tungsten in methane-hydrogen atmospheres and tungsten in contact with carbon indicate a eutectoid reaction $W_2C(s) \rightarrow WC(s) + W(s)$ at 1300°C and a peritectoid reaction $2WC(s) \rightarrow W_2C(s) + C$ (graphite) at 1760°C. Lower temperatures are indicated by the methane-hydrogen studies, presumably due to decomposition of methane in this temperature range. The triple point on the pressure-temperature diagram is calculated from the heat of formation for WC and free energy of formation of W_2C. A W-C phase diagram incorporating the eutectoid and peritectoid reactions is presented.

23,551 PRESSURE-INDUCED TRANSFORMATIONS TO CRYSTAL STRUCTURES OF LOWER PACKING DENSITY by F.K. Weddeling (Duke U.); J. Appl. Phys., Vol. 35, pp. 1201-1202, Apr. 1964

An explanation of pressure-induced polymorphic transitions from close-packed structures to nonclose-packed arrangements of atoms is attempted and compared with recent experimental data for ytterbium.

23,552 THE CRYSTALLOGRAPHIC MECHANISM OF PHASE TRANSITIONS IN THIN METAL FOILS [in German] by H. Koritke and W. Pitsch (Max-Planck Inst.); Acta Met., Vol. 12, pp. 417-429, Apr. 1964

The crystallographic properties of phase transitions in thin foils has been measured in the electron microscope on an electrically heated specimen holder. The following phase transitions were investigated: the precipitation of cementite $(Fe,Mn)_3C$ (Z) from austenite (A) and the precipitation of the iron nitrides Fe_8N(n) and Fe_4N(N) from the ferrite (F). Within a certain scatter the following results were obtained: The orientation correlation 1. $[100]_Z \parallel [5\bar{5}4]_A$, $[010]_Z \parallel [110]_A$, 2. $[100]_n \parallel [100]_F$, $[010]_n \parallel [010]_F$, and 3. $[100]_N \parallel [\bar{0}.\bar{7}4\ \bar{0}.67\ \bar{0}.\bar{0}7\bar{5}]_F$, $[010]_N \parallel [0.65\ 0.74\ 0.17]_F$. In the thin foils used in the experiments the prefered growth directions of the new phase are directions from the planes with the normals 1. $<1.60l>_Z$, 2. $<100>_n$, and 3. $<112>_N$. In cementite the internal structure consists of a fibrous structure along $[010]_Z$, and in the nitride Fe_4N it consists of a lamella structure along the planes $\{111\}_N$. The nitride Fe_8N does not have a special internal structure. The present results are compared with corresponding results obtained on compact specimens. This comparison is also extended to other phase transitions discussed in literature. Obviously the crystallographic mechanism of phase transitions in the specimens used is principally similar to the phenomena in compact materials.

23,553 EFFECT OF IMPERFECTIONS ON THE α TO β TRANSFORMATION IN PURE TIN by C.G. Durdaller (U. Pennsylvania); Bull. Am. Phys. Soc., Vol. 9, p. 272(A), Mar. 1964

The effect of imperfections on the rate of nucleation in the α to β transformation in 99.999 per cent tin has been studied by dilatometric measurements at supersaturations ranging from 7.2°-21.5°C. Five particle-size ranges were used, ranging from 0.6 to 15-20 μ in diameter. The nucleation rate was found to be extremely sensitive to particle size. This sensitivity can well be understood by assuming that the imperfections introduced into the particles during preparation served as sites for nucleation. This leads to a self-consistent analysis of nucleation. The nucleation process appears to be quite complex, and the rate is dependent upon the kind of imperfection present, the test temperature, and the elapsed time of nucleation. The over-all nucleation in each particle-size range is composed of several parts. These characteristic parts enter into the nucleation process at different times, depending upon the test temperature. This observation suggests that there are unambiguous transient times for nucleation in this transformation. All the nucleation curves can be fitted by a rate equation developed assuming that the imperfections are statistically distributed among the particles.

23,554 PHASE TRANSITIONS IN ANTIMONY AT HIGH PRESSURES by S.S. Kabalkina and V.P. Mylov (Acad. Sci. USSR); Soviet Phys.-Doklady, Vol.8, pp. 917-918(L), Mar. 1964

An X-ray study of the structure of antimony at pressures of 30, 50, 90 and 100[illegible] kbars is reported. The results show that at 50 kbars, antimony undergoes a reversible phase transition which is accompanied by a transformation of the initial rhombohedral lattice into a primitive cubic lattice. At 90 kbars, Sb has a hexagonal close-packed structure. Phase transformations in Sb are then accompanied by an increase in the coordination number.

Phase Transformations in:
$CrCl_3$ - See 23,579
H_2S (Solid) - See 23,580
PbS, PbSe and PbTe - See 23,978

Order-Disorder Transitions in:
$CaO-Y_2O_3-ZrO_2$ - See 23,989
ZrO-CaO - See 23,988

23,555 EFFECT OF LONG-RANGE INTERACTIONS ON ORDER by A. Paskin (Brookhaven Lab.); Phys. Rev., Vol. 134(A), pp. A246-249, Apr. 6, 1964

Harrison and Paskin (HP) have calculated the ordering energy of β-CuZn using theoretical techniques of treating electron screening and Mott's polar model of an alloy. Good agreement is obtained between the calculated total energy of the order-disorder transformation and specific-heat measurements. A consequence of the HP calculation is that the ordering energy is long-range and oscillates in sign. Walker and Keating have measured the neutron diffuse scattering of β-CuZn above the critical temperature T_c and found their data to be in agreement with order calculated by only considering a nearest-neighbor interaction. Using the Cowley statistical theory of order, the order generated by a nearest-neighbor interaction is compared with the long-range interaction of HP at a temperature $1.1\,T_c$. The average behavior of the order generated by the nearest-neighbor and long-range interaction is found to be similar. The major difference is that the nearest-neighbor interaction generates order which asymptotically varies smoothly with neighbor distance, whereas the order resulting from the long-range interaction fluctuates markedly about the nearest-neighbor generated order. This result may explain the success of statistical theories, based on nearest-neighbor interactions, in both order-disorder of alloys as well as in some magnetic systems which are also believed to have a similar long-range oscillatory interaction.

23,556 THE INFLUENCE OF QUENCHED-IN VACANCIES ON THE ORDERING RATE OF THE Cu_3Au ALLOY by S. Benci, G. Gasparrini and E. Germagnoli (U. Parma, Italy); Nuovo Cimento, Vol. 31, pp. 1165-1175, Mar. 1964

The development of order below the critical temperature in fully disordered Cu_3Au specimens is enhanced by quenched-in lattice vacancies. From the ordering rate and from the decrease in resistivity due to order the activation energies for vacancy formation (1.00 ± 0.06) ev and for vacancy migration (0.72 ± 0.06) ev are deduced. It is also noticed that the ordering process displays some anomalous features whenever the quenching temperature is above 600°C.

23,557 X-RAY EVIDENCE OF SHORT RANGE ORDER IN Au-Pd SYSTEM by W.D. Copeland and M.E. Nicholson (U. Minnesota); Acta Met., Vol. 12, pp. 321-322(L), Mar. 1964

The occurrence of short range order in the Au-Pd system and its detection by means of a diffuse X-ray scattering technique are described. The existence of a pronounced positive deviation from the Laue monatomic curve in the region just prior to the first Bragg peak, and the destruction of this peak upon cold work and increasing temperature are cited as strong qualitative evidence for the existence of short range order in this system. A short range order parameter, $\alpha < 0$ is predicted.

23,558 ANTIPHASE DOMAINS IN ORDERED Au_3Cu ALLOYS by R.S. Toth and H. Sato (Ford Motor); J. Appl. Phys., Vol. 35, pp. 698-703, Mar. 1964

Alloys having compositions from 42%-9% Cu in the Cu-Au system have been investigated to determine the nature of the antiphase structures and the range of the ordered Au_3Cu structure in this region. The single-crystal thin-film technique was used to prepare the specimens and the structure was determined by electron diffraction. The ordered Au_3Cu I structure exists as an equilibrium phase from 38.5%-9% Cu. Unlike the Cu_3Au and CuAu alloys, however, periodic antiphase structures are not observed as an equilibrium phase in these alloys. Increasing the electron-atom ratio by the addition of a third element, for example, Al, results in the formation of a periodic antiphase structure as predicted. It is shown that the low ordering temperature is responsible for the failure of a periodic antiphase structure to appear in these alloys.

CRYSTAL STRUCTURE

GENERAL

23,559 STRUCTURE-FACTOR AND LEAST-SQUARES EXPRESSIONS FOR CU-

C CRYSTAL SYSTEMS WITH ISOTROPIC VIBRATIONS by N. Webb (Calif. t. Tech.); Acta Cryst., Vol. 17, pp. 69-71(L), Jan. 1964

et of expressions is presented for calculating structure-factors and least-are coefficients for cubic structures with isotropic temperature factors. ese expressions are for use with electronic computers; only the space group nber is necessary to direct the calculations. All geometrical structure fac-s have been reduced to sums of triple products of sines and cosines. Tables factors are included.

,560 SOME CRYSTALLOGRAPHIC PROGRAMS FOR THE COMPUTERS, SK AND FACIT EDB by R. Liminga and I. Olovsson (U. Uppsala, Sweden); ta Polytech. Scandinavica. Math. and Computing Mach., Series 10, Up-ila, 1964, pp. 3-12

eries of programs for the calculation of structure factors and summation of urier series is described. These programs can handle practically all space oups without writing subroutines. The reflexions can occur in any order and sorting is necessary between changes of the summation order. The intervals e completely general. A program for systematic evaluation of distances and gles is also described. The programs have been written for the Swedish com-ters BESK and FACIT EDB.

,561 THE EMPIRICAL FORMULAE OF INTERMETALLIC COMPOUNDS BY EUTRON ACTIVATION by H. Simpson (Wantage Res. Labs., England); Acta yst., Vol. 17, pp. 59-60(L), Jan. 1964

e application of neutron activation analysis to the determination of the em-ical formula of technetium-aluminum and molybdenum-aluminum compounds reported. An outline of the technique is given since this method is generally plicable, particularly when accurate results are required from small samples. e results are sufficiently consistent to indicate the crystallographic formula milligram samples.

,562 ON THE DESIGN OF SINGLE CRYSTAL DIFFRACTOMETERS TO EASURE A NUMBER OF REFLECTIONS SUMULTANEOUSLY by D.C. Phil-s (Royal Inst., London); J. Sci. Instr., Vol. 41, pp. 123-129, Mar. 1964

ngle-crystal diffractometers derived from inclination Weissenberg goniom-ers can be adapted to measure more than one reflection at a time. Two re-ections can be measured simultaneously, one from each of any two levels at are symmetrically on either side of the flat-cone setting, or several re-ections can be measured quasi-simultaneously, one from each level within out ± 0.05 r.l.u. of the flat-cone setting. The modifications which permit ese new modes of operation are described, together with corresponding anges in the design and use of four-circle diffractometers. The general re-tionships between the two types of diffractometer are also discussed.

,563 DIFFUSE STREAK DIFFRACTION PATTERNS FROM SINGLE CRYSTALS rt I. GENERAL DISCUSSION AND ASPECTS OF ELECTRON DIFFRACTION FFUSE STREAK PATTERNS by G. Honjo, S. Kodera and N. Kitamura (Tokyo st. Tech.); J. Phys. Soc. Japan, Vol. 19, pp. 351-367, Mar. 1964

ffuse streak patterns from single crystals which have recently been noticed electron diffraction are identified with the "non-radial" streak patterns in -ray diffraction and their description in terms of parallel wall distribution of tensity weight along low index reciprocal net planes is discussed. Evidences r the description in electron diffraction patterns from silicon, germanium, uminum, gold, iron, sodium and potassium chlorides and barium titanate are lustrated. An assumption of linear chain scatterers consisting of a small num-er of nearest neighbor atoms shifted from their regular positions is shown to be ble to reproduce the characteristic features of the streak patterns from diamond ructure and simple face centered cubic structure. Applicability of similar as-mptions to the other cases is suggested.

3,564 NEUTRON DIFFRACTION EFFECTS WITH MOVING LATTICES by .G. Shull and N.S. Gingrich (MIT); J. Appl. Phys., Vol. 35, pp. 678-682, lar. 1964

bservations are reported on the effect of specimen motion upon the neutron iffraction pattern of iron. Specimen speeds of 120 msec combined with a neu-on speed of 3310 msec are found to produce easily measured angular shifts, ntegrated intensity changes, neutron wavelength alteration, and peak width hanges, all of which are dependent upon the direction of motion relative to e scattering vector. The effects can be conveniently interpreted with the re-iprocal lattice construction and the calculated changes with motion agree atisfactorily with the observations.

3,565 SPACE GROUP IDENTIFICATION BY PROTON MAGNETIC RESO-NANCE by R. Chidambaram (Atomic Energy Estab., India); Acta Cryst., Vol. 7, p. 456(L), Apr. 1964

is often possible to resolve ambiguities in identification of the space group f a crystal determined by X-ray diffraction by examining the magnetic reso-ance pattern of the protons in the crystal. Application of the method is lim-ited to crystals containing H_2O molecules or CH_2 groups, i.e., 2-proton systems, because of difficulty in unscrambling experimental curves. The method consists of determination of the length and orientation of the inter-proton (p-p) vector by studying the doublet separation in the resonance pattern. In order to identify space groups, the number of non-parallel p-p vectors in the unit cell and their mutual symmetry relationships for the space group choices provided by X-ray measurements are calculated. The true space group is that calculated which best fits the experimental pattern.

23,566 ABSORPTION AND OTHER ERRORS IN THE MEASUREMENT OF THE INTENSITIES OF X-RAY REFLEXIONS FROM SINGLE CRYSTALS by J.W. Jeffery and K.M. Rose (Birkbeck Coll., England); Acta Cryst., Vol. 17, pp. 343-350, Apr. 1964

The origins of the tendency to underestimate absorption errors are discussed and it is pointed out that in most cases where accurate measurements are made, either photographically or by counter methods, the errors due to absorption in the crystal are greater than recording errors. These experimental results on a number of crystals combined with the tabulated values of A*, the absorption correction factor for spherical crystals, permit calculation of a factor, β, which relates the coefficient of variation of intensity, $\nu(I)$, to the coefficient of variation of the crystal radius, $\nu(r)$. $\nu(r)$ is obtained from photomicrographs of the crystal. For values of μr less than 0.4, $\nu(I)$ is independent of θ, but for crystals above this value it varies in a somewhat complicated way with the Bragg angle. $\nu(I)$ is calculated for a number of typical cases and the relative advantages of counter and photographic recording are discussed in the light of these results, together with the considerations leading to the choice of Mo or Cu radiation. The values of $\nu(I)$ can be used to form weights for least-squares correlation of photographs of different reciprocal lattice layers or for the refinements of structure parameters. The calculations involved can be simply programmed for an electronic computer.

23,567 VOCABULARY OF SURFACE CRYSTALLOGRAPHY by E.A. Wood (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 1306-1312, Apr. 1964

The recent increase of activity in the field of slow-electron diffraction has resulted in a need for agreement on conventions of terminology in the description of a diperiodic surface structure relative to a triperiodic substrate. Vector description of the surface structure net in terms of the substrate surface net is suggested. Fractional Miller indices result when the surface structure mesh is larger than the substrate surface mesh. The surface structure may be either that of a deposit or that of the selvedge of the substrate. With the relaxation of one of the diffraction conditions in the diperiodic structure, the reciprocal lattice becomes a set of parallel rods intersecting the Ewald sphere continuously with change of wavelength of the incident radiation or change of orientation of the crystal. The applicability of the seventeen two-dimensional space groups and the eighty diperiodic groups in three dimensions to these diperiodic structures is discussed. A comparison is made between the different effects of surface symmetry on etch pits and epitaxial deposits on the cleavage face of muscovite.

23,568 SELECTED AREA X-RAY DIFFRACTION STUDIES OF SURFACE DAMAGE IN SLIDING ON SINGLE-CRYSTAL COPPER by D.D. Roshon, Jr. (IBM); J. Appl. Phys., Vol. 35, pp. 1262-1269, Apr. 1964

Selected area X-ray diffraction was employed to study the localized structural changes resulting from sliding of a hemispherical copper stylus on the (001) face of a copper single crystal. Although a relatively large (0.25 mm) X-ray beam was used, significant structural deformations were resolved. Features observed included deformation of boundary regions by rotation from slip, crystal bending in areas of pileup, the microcrystalline Beilby layer, a preferentially oriented transition region, and transferred crystalline particles. The observed deformations exhibited a dependence on sliding direction.

23,569 ELECTRON MICROSCOPE STUDIES OF THE SURFACE STRUCTURE OF WHISKERS GROWN FROM IRON CHLORIDE by A. Revere; Nov. 1963, 29 pp., Contract AF33 657 8554, Proj. 7353; U.S. Gov. Res. Rep., Vol. 39, p. 134(A), Apr. 20, 1964 AD 429 183 OTS $3.60

Evidence has been obtained concerning the mechanism of filamentary growth as it is reflected in surface structure. Whisker specimens have been produced under new types of growth conditions with ultra-pure ferrous chloride containing small amounts of cobaltous chloride at 700°C. Although individual whiskers within each specimen boat may vary somewhat, their surface topography appears to follow definite patterns. In most specimens, regardless of growth conditions, these typical patterns show variation in surface structure from the base to the tip areas. Detail in surface contours appears to be more uniform in whiskers which develop well-formed tips. When whiskers grown with the addition of cobaltous chloride could be broken, their fractured cross-section surfaces exhibited a shell and core structure similar to that found in whiskers previously studied.

23,570 SOME OBSERVATIONS ON THE INTERFACIAL TOPOGRAPHIES OF ALUMINUM AND ITS AMORPHOUS OXIDE by J.J. Randall, Jr. and W.J. Bernard (Sprague Electric); J. Appl. Phys., Vol. 35, pp. 1317-1322, Apr. 1964

The thin amorphous oxide formed in air on electropolished aluminum replicates the surface of the metal, resulting in identical topographies at the metal-oxide and oxide-oxygen interfaces. The observed configurations are attributed to surface features developed in the metal during electropolishing; these features vary widely depending upon electropolishing conditions. The formation of crystalline oxide at 600°C occurs at the metal-amorphous oxide interface even in the presence of thick amorphous layers formed by anodic oxidation. Evidence is given that cracks develop in the amorphous film on heating and that subsequent thermal oxidation proceeds through these defects.

23,571 THE TOPOGRAPHY AND GROWTH MECHANISM OF SILICON OVERGROWTHS by A.G. Revesz and R.J. Evans (RCA Labs.); Trans. Met. Soc. AIME, Vol. 230, pp. 581-585, Apr. 1964

Silicon films have been grown by chemical reaction on (111) silicon substrates. The surfaces were examined by various microscopic and interferometric methods. Surface structures are classified into two groups depending on whether the angles between the bounding planes and the (111) surface are small (< 3 deg) or large (> 10 deg). A layer-growth mechanism is postulated to explain the topography and the influence of growth parameters. Growth proceeds by lateral expansion of the (111) layers in $<2\bar{1}\bar{1}>$ directions, thereby forming steps. The step edges are perpendicular to the direction of expansion and are thus along <110> directions. Step bunching and surface nucleation both play an important role in modifying the flow pattern and in the step regeneration. These are influenced very much by impurities, especially oxygen. Although the growth is a result of a surface-controlled gas reaction, it is very similar to growth from an impure solution.

23,572 LOW-ENERGY ELECTRON DIFFRACTION STUDIES OF (100) AND (111) SURFACES OF SEMICONDUCTING DIAMOND by J.B. Marsh and H. E. Farnsworth (Brown U); Surface Sci., Vol. 1, pp. 3-21, Jan. 1964

The low-energy electron diffraction technique has been used to investigate (100) and (111) surfaces of semiconducting diamond single crystals. The surfaces were covered with a stable layer of contamination which yielded diffraction patterns characteristic of the normal diamond lattice spacing. Attempts to remove the contamination by thermal out-gassing or ion bombardment and annealing in vacuum resulted in surfaces which were unsuitable for diffraction measurements. Essentially clean (111) and (100) surfaces were obtained, however, by heating the crystals in a hydrogen ambient under suitable conditions of temperature and pressure. The intensities of the diffraction patterns which resulted from this treatment were as much as 20 times those observed prior to heating in hydrogen, and the patterns also contained very weak half-integral order beams. Neither the (100) or (111) surface adsorbed oxygen readily at room temperature as indicated by the low value of the sticking coefficient for oxygen ($S < 10^{-6}$). At room temperature, oxygen adsorbed on the (111) surface in a crystalline layer but adsorption on the (100) surface was primarily amorphous at this temperature. At elevated temperatures, crystalline adsorption occurred on both faces, indicating the presence of an activation energy. Heating the diamond crystals in vacuum at temperatures in excess of 450°C carbonized the surfaces. Mass spectrometer analysis of the gaseous products released from the surface indicated that surface carbon was removed by hydrogen primarily in the form of CH_4 and by O_2 in the form of CO and CO_2.

23,573 X-RAY RADIOGRAPHS TAKEN WITH SILICON SINGLE CRYSTAL WAFERS BY DIVERGENT X-RAY METHOD by T. Fujiwara, S. Dohi and J. Sunada (Def. Acad., Yokosuka); Japanese J. Appl. Phys., Vol. 3, pp. 129-131, Mar. 1964

X-ray radiographs of broad Laue spots with X-ray spectral lines taken on wafers of silicon single crystals of various kinds are described. On each of the Laue-spots, many X-ray spectral lines of various shapes and ground figures consisting of somewhat broadened lines straightened or curved, were observed. It is considered that these X-ray spectral lines and the ground figures of the Laue-spots are mostly produced by the dislocations and other imperfections in the crystal wafer, and that from the appearances of these X-ray spectral lines and ground figures the bodily distribution of the dislocations and other imperfections can be found.

23,574 CRYSTALLOGRAPHIC IMPLICATIONS OF EPR IN NEUTRON-IRRADIATED DIAMOND by R.M. Denning (U. Michigan) and E.H. Poindexter (California Res. Corp.); Am. Mineralogist, Vol. 49, pp. 277-285, Mar.-Apr. 1964

Diamonds irradiated with fast neutrons have been studied by electron paramagnetic resonance (EPR). The concentration of free spins and the line width of the signal have been studied as a function of total irradiation, before and after heat treatment. The signal intensity is proportional to total integrated radiation to 10^{18} nvt (fast). The EPR intensity decreases rapidly after heat treatment. The line widths are independent of radiation up to 10^{17} nvt, and they also decrease markedly after heat treatments. The EPR phenomena in irradiated diamond are quite different from those in graphite. It is suggested that highly irradiated diamond is a mosaic of microcrystals separated by a cement of damaged, amorphous, diamond-like glass. The conclusions of the EPR study support similar conclusions based on cleavage surface optical reflections and differential grinding hardness.

23,575 HIGH PRESSURE METALLIC INDIUM TELLURIDE: PREPARATION AND CRYSTAL STRUCTURE by C.B. Sclar, L.C. Carrison, and C.M. Schwartz (Battelle); Science, Vol. 143, pp. 352-353, Jan. 24, 1964

The metallic high pressure form of indium telluride may be prepared under high pressure at 150°C and retained at ambient conditions without low temperature quenching. It has the NaCl (B1) structure with a cell edge of 6.160 ± 0.005 A and a calculated density of 6.887 g/cm^3. The density increase relative to the low pressure polymorph is 15.6 per cent.

23,576 CRYSTAL STRUCTURE OF α-$C_{10}H_7HgI$ by V.I. Pekhomov (Acad. Sci. USSR); Soviet Phys.-Cryst., Vol. 8, p. 630(L), Mar.-Apr. 1964

An X-ray analysis of the crystal structure of the naphthalene derivative α-$C_{10}H_7HgI$ is reported. The results show that the unit cell is monoclinic with $a = 8.72$, $b = 5.08$, $c = 10.19$, $\beta = 97°13'$, $Z = 2$. From the Patterson projections, the coordinates of the mercury and iodine atoms were found. A geometrical analysis shows that the naphthalene ring is positioned in space with a symmetry corresponding to the space group $P2_1$, and the arrangement of Hg-I bonds in space can be described by the group $P2_1/m$.

23,577 STRUCTURAL PECULIARITIES OF ZINC SULPHIDE, CADMIUM SULPHIDE, CADMIUM TELLURIDE AND GALLIUM PHOSPHIDE by E.J.M. Kendall (Hendon Coll. Tech.); Phys. Lett. (Neth.), Vol. 8, pp. 237-238(L), Feb. 15, 1964

Gradual changes in crystal structure which give rise to quasi p-n junctions, and thus effect the electrical and optical properties of crystals, are discussed. Gradual changes have been predicted to occur in I-VIII (AgI), II-VI (ZnS, CdS, CdTe, MnS, and MnSe) and III-V (GaP) compounds, and have been experimentally observed in ZnS, CdS, CdTe, and GaP. In ZnS both hexagonal close-packed (hcp) and cubic close-packed (ccp) structures were observed, with the proportion of hcp decreasing with time. A transitory rhombohedral form was also observed. The CdS samples initially contained a small amount of hcp structure, which soon inverted to a quasi-stable rhombohedral form and then to the ccp form. In the CdTe samples, the ccp phase was predominant, with only a few lines indicating hcp. The main structural component of the GaP crystals was ccp, with evidence of both rhombohedral and hcp structures. An extremely slow rate of structural change was observed in CdTe and GaP.

23,578 STUDIES ON A NEW POLYTYPE OF CADMIUM IODIDE $28H_c$ by O. N. Srivastava and A.R. Verma (Banaras Hindu U.); Acta Cryst., Vol. 17, pp. 260-264, Mar. 1964

A twenty-eight layered new polytype of cadmium iodide, designated $28H_c$, with unit-cell dimensions $a = 4.24$, $c = 95.69$ A, is described. The detailed atomic structure has been worked out and its zigzag sequence is found to be 2222222222221111. The growth of the polytype is examined in the light of the screw dislocation theory of polytypism. The screw dislocation theory is not able to explain fully the growth of this polytype. The polytype $28H_c$ is so far the largest cadmium iodide polytype with a known atomic structure.

23,579 X-RAY DIFFRACTION AND NUCLEAR QUADRUPOLE RESONANCE STUDIES OF CHROMIUM TRICHLORIDE by B. Morosin and A. Narath (Sandia Lab.); J. Chem. Phys., Vol. 40, pp. 1958-1967, Apr. 1, 1964

The infinite-layer compound $CrCl_3$ is found to undergo a first-order phase transformation near 240°K. The crystal structures of the high- and low-temperature phases have been elucidated by detailed X-ray diffraction and ^{35}Cl nuclear quadrupole resonance studies. The previously reported structure for $CrCl_3$ is shown to be incorrect. The present single-crystal diffraction results at 298° and 225°K give monoclinic ($C2/m$: $a_0 = 5.959$ A, $b_0 = 10.321$, $c_0 = 6.114$ A, $\beta = 108.49°$) and rhombohedral ($R\bar{3}$: $a_0 = 5.942$ A, $c_0 = 17.333$ A) structures, respectively. The ^{35}Cl quadrupole resonance frequencies, measured in polycrystalline samples, have been compared with results of field-gradient calculations based on the ionic point-charge model. The ionic contribution accounts for a large fraction of the total gradient making it impossible to evaluate the covalency parameters of the Cr-Cl bonds from the measured quadrupole coupling constants.

23,580 STRUCTURE AND PHASE TRANSITION OF SOLID HYDROGEN SULPHIDE by J. Harada and N. Kitamura (Tokyo Inst. Tech.); J. Phys. Soc. Japan, Vol. 19, pp. 328-343, Mar. 1964

By electron diffraction and X-ray diffraction, the following facts have been found: (1) A new tetragonal structure ($a = 13.5$ A and $c = 4.14$ A) exists below a transformation point at about -168°C. (2) This structure changes (at -168°C) to the cubic structure which is already known, after changing into a transient tetragonal structure ($a' = 1/2 \cdot a$ and $c' = c$). (3) The cubic structure shows a volume change of about 2 per cent at a higher transformation point at -147°C. The arrangement of sulphur atoms in the transient tetragonal form has been determined from Patterson synthesis and a trial and error method on the basis of electron diffraction data. The structure is composed of double zigzag chains of sulphur atoms along the c-axis. The stable tetragonal structure of the lowest temperature phase is considered to be a super-structure of the intermediate form.

The relations between these lattice transformations and changes of physical quantities are discussed.

23,581 THE STRUCTURE OF QUADRATIC CUPROUS SULFIDE [in French] by A. Jánosi (U. de Louvain, Belgium); Acta Cryst., Vol. 17, pp. 311-312, Mar. 1964

A new form of copper sulfide has been obtained by thermal synthesis of the elements at 140°C. Diffraction patterns of $Cu_{1.96}S$ (quadratic) powder yield the parameters a = 3.996 A, c = 11.28 A, c/a = 2.824. Calculated density is 5.770 g cm^{-3}. The sulfur atoms are displaced from cubic close packing and copper atoms occupy one of the four trigonal positions surrounding each tetrahedral position. Each sulfur atom is surrounded by two sulfur atoms at 3.99 A and six copper atoms at 2.31 A. Copper atoms are surrounded by three sulfur atoms and the Cu-Cu distances are 2.64, 2.97, and 3.53 A.

23,582 STRUCTURES OF TWO POLYMORPHIC FORMS OF Cu_5FeS_4 by N. Morimoto (U. Tokyo); Acta Cryst., Vol. 17, pp. 351-360, Apr. 1964

There exist three polymorphic forms of Cu_5FeS_4. All three can be obtained by starting with natural or synthetic material. A high-temperature form, stable above 228 ± 5°C, changes to a transitional metastable form on cooling below 228 ± 5°C; it then gradually changes to the low-temperature form. Only the latter occurs in nature, as bornite. The crystal structure of the high-temperature form has been determined from single-crystal data. The cubic cell with a = 5.50 A contains Cu_5FeS_4. The space group is Fm3m. The S atoms occupy the nodes of the face-centered cubic lattice. In each tetrahedron of S atoms, the metal atom is statistically distributed among 24 equivalent sites with coordinates x = 0.310, y = 0.290, and z = 0.270, the total metal atom in the tetrahedron being 3/4 (Cu,Fe). The crystal structure of the metastable form of synthetic bornite has also been determined. The space group is Fd3m, with a = 10.94 A, but the cubic symmetry results from the twinning of small domains with rhombohedral symmetry in eight different orientations. Each individual in this twin has space group R3m, with a_{rh} = 6.70 A and α = 33°32′. In this rhombohedral structure all the sulfur atoms remain in cubic close-packing. The metal atoms are situated in three out of every four tetrahedra; they are statistically distributed among four equivalent sites inside each occupied tetrahedron. No distinction was made between Cu and Fe atoms, either in the metastable structure or in the high-temperature structure. The low-temperature form shows space group $P42_1c$ with a = 10.94 and c = 21.88 A. A structural mechanism is proposed for the polymorphic transition between the high-temperature and the metastable forms.

23,583 THE STRUCTURE OF $SrZn_2$ by B. Bergman and P. Shlichta (California Inst. Tech.); Acta Cryst., Vol. 17, pp. 65-66(L), Jan. 1964

A study of the strontium-zinc system has disclosed a phase, in slowly cooled alloys of 40-60% wt. zinc, characterized by prismatic crystals embedded in a eutectic mixture. Laue photographs from a single crystal, 0.2 mm long, indicate orthorhombic symmetry. The unit-cell edges were a 2 4.78 A, b ≃ c = 7.80 A. Complete data are reported. It is concluded that the structure is of the same type as that of $CeCu_2$.

23,584 CRYSTAL STRUCTURES OF COMPOUNDS OF RARE-EARTH METALS WITH BERYLLIUM (RBe_{13}) by E.I. Gladyshevskii, P.I. Kripyakevich and D.P. Frankevich (Franko L'vovsk State U.); Soviet Phys.-Cryst., Vol. 8, pp. 628-629(L), Mar.-Apr. 1964

An X-ray structural investigation of the compounds of rare-earth metals with beryllium (RBe_{13}) is reported. It is found that all the alloys consist exclusively of $NaZn_{13}$ type phases. The unit cell constants increase regularly with the increase in the atomic number of R.

23,585 THE STRUCTURE OF (Ti,Re)Si_2 by W. Duffin, E. Parthé and J.T. Norton (MIT and U. Pennsylvania); Acta Cryst., Vol. 17, pp. 450-451, Apr. 1964

Specimens in the pseudo-binary system $ReSi_2$-$TiSi_2$ have been prepared by hot pressing stoichiometric mixtures of the powdered elements. A hexagonal ternary phase occurs with the approximate composition $Ti_{0.9}Re_{0.1}Si_2$ and lattice parameters a = 4.70 A, c = 6.50 A, c/a = 1.38. $ReSi_2$ dissolves about 15 mol percent $TiSi_2$ while the solubility of $ReSi_2$ in $TiSi_2$ is less than 5 mol per cent. The results obtained can be interpreted by a valence electron factor; $TiSi_2$ crystallizes with the 4-layer stacking type while pure $ReSi_2$ chooses the 2-layer stacking type. By replacing some of the Ti atoms by the electron-richer Re atoms, the intermediate 3-layer stacking type is obtained.

23,586 THE STRUCTURE OF HfSn by O. Schob and E. Parthé (U. Pennsylvania); Acta Cryst., Vol. 17, pp. 452-453, Apr. 1964

The compound HfSn has been synthesized by pressing hafnium hydride and tin powders under purified argon at 1000°C. The powder pattern could be indexed with a cubic unit cell with the lattice constant a = 5.594 A. Calculated X-ray density is 11.27 g cm^{-3}. The space group for HfSn is $P2_13(T^4)$ with only one fourfold position having one adjustable parameter. The structure of HfSn belongs to the FeSi(B20) structure type. HfSn is the first known B20 structure compound with a transition metal of the fourth group.

23,587 THE CRYSTAL STRUCTURE OF $ScCd_3$ by R.V. Schablaske, B.S. Tani, and M.G. Chasanov (Argonne Natl. Lab.); Trans. Met. Soc. AIME, Vol. 230, pp. 248-249(L), Feb. 1964

The crystal structure of intermetallic compound $ScCd_3$ has been established by means of the X-ray powder diffraction technique. On the basis of stoichiometry, symmetry, unit cell dimensions and the number of atoms per unit cell a $Mg_3Cd(D0_{19})$ type structure is given for $ScCd_3$; the space group is D_{3h}^4-$P6_3/mmc$. Atomic coordinates for the 8 atoms in the unit cell are reported. Lattice constants are a_0 = 6.330 ± 0.001 A to 6.324 ± 0.001 A and c_0 = 4.853 ± 0.001 A. The a_0 is reported to have a slight range with the lower value seemingly associated with the cadmium-rich terminus of the phase. The measured value for the density of $ScCd_3$ is 7.7 g/cu cm compared with the calculated X-ray density value of 7.54 g/cu cm. The existence of another intermetallic compound ScCd in this system having the CsCl(B2) type structure, with lattice constant a_0 = 3.513 ± 0.002 A is also confirmed.

23,588 THE CRYSTAL STRUCTURE OF ThPd by J. Thomson (Imperial Coll. of Sci., England); Acta Cryst., Vol. 17, pp. 64-65(L), Jan. 1964

The crystal structure of the Th-Pd binary system is discussed. In particular, the intermetallic compound at 50 at. per cent Pd has been prepared and X-ray powder patterns have been obtained with a Guinier-type focusing camera. Cu radiation and a quartz monochromator (λ K α_1 = 1.54050 A) were used; the line intensities were visually estimated. It is stated that isotypes of ThPd include ThSi, ZrSi, FeB, and GdPt.

23,589 χ PHASE IN A NIOBIUM-RHENIUM ALLOY by R. Steadman and P. Nuttal (Bradford Inst. Tech., England); Acta Cryst., Vol. 17, pp. 62-63(L), Jan. 1964

A single crystal investigation of the χ phase of Nb-Re to obtain information on the ordering of crystallographic sites is discussed. The R value obtained was 0.22. A zero-layer Weissenberg photograph was taken with Mo K α radiation using a multiple-film pack; the spots were integrated to facilitate the measurement of intensities. A table of results is included.

23,590 STRUCTURE OF NIOBIUM CARBIDES [in French] by N. Terao (Union Carbide European Res. Assoc.); Japanese J. Appl. Phys., Vol. 3, pp. 104-111, Feb. 1964

The preparation of thin films of two niobium carbides, NbC and Nb_2C, for electron diffraction studies has been accomplished by heating in vacuo double evaporated films (carbon + Nb). NbC is formed by a carburization process in high vacuum, while thin films of Nb_2C are produced by decomposition of NbC in air at reduced pressure ($10^{-2} \sim 10^{-3}$ Torr) by the reaction $2\,NbC + O_2 \rightarrow Nb_2C + CO_2$. The crystal structure of NbC is based on the fcc lattice of Nb atoms and the carbon atoms occupy interstitial positions in a statistical manner. Nb_2C, however, shows a hexagonal superlattice structure of the same type as that of the ε-phase of Fe_2N.

23,591 CRYSTAL STRUCTURE AND MAGNETIC PROPERTIES OF $CoTiO_3$ by R.E. Newnham, J.H. Fang and R.P. Santoro (MIT); Acta Cryst., Vol. 17, pp. 240-242, Mar. 1964

The crystal structure of cobalt titanate, $CoTiO_3$, has been refined by least-squares analysis of X-ray and neutron-diffraction data. Magnetic susceptibility measurements on polycrystalline samples gave a nearly ideal antiferromagnetic susceptibility curve with a Néel temperature of 38°K. The ordered magnetic structure at low temperatures is identical with that of $NiTiO_3$ in which the spin direction is perpendicular to the rhombohedral [111] direction. Within each (111) plane the Co^{2+} moments are ferromagnetically coupled, but alternate layers are antiparallel.

23,592 THE CRYSTAL STRUCTURE OF $UMoC_2$ by D.T. Cromer, A.C. Larson and R.B. Roof, Jr. (Los Alamos Lab.); Acta Cryst., Vol. 17, pp. 272-276, Mar. 1964

The structure of $UMoC_2$ has been determined from single-crystal X-ray data. The orthorhombic unit cell has the dimensions a = 5.625, b = 3.249 and c = 10.980 A. There are four formula units per unit cell and all atoms are on the mirror planes in set 4(c) of space group Pnma. In the least-squares refinement of the structure a secondary extinction parameter and the real and imaginary portions of the anomalous dispersion corrections were used. The correction of Fourier coefficients for structures with anomalous scatters is discussed. There are no short C-C distances and this compound is not an acetylene type carbide.

23,593 CRYSTALLINE PARAMETERS AND POSITION SYMMETRY GROUP OF MAGNESIUM SULFITE TRIHYDRATE, $MgSO_3 \cdot 3H_2O$ [in French] by J. Wendling and R. Weiss (U. Strasbourg, France); Acta Cryst., Vol. 17, p. 66(L), Jan. 1964

The crystalline parameters and symmetry positions of $MgSO_3 \cdot 3H_2O$ are dis-

cussed. The crystal is orthorhombic; the symmetry class is mm2. Weak piezoelectric properties are observed. Some crystallographic data are included.

23,594 A CRYSTALLOGRAPHIC STUDY OF $Nb_2O_5 \cdot 3WO_3$ by G. Mohanty and L. Fiegel (A.O. Smith Corp.); Acta Cryst., Vol. 17, p. 454(L), Apr. 1964

Single crystals of the compound $Nb_2O_5 \cdot 3WO_3$ have been grown and isolated for diffraction study. Confirmation of a tetragonal unit cell was made with measured lattice parameters a = 12.130 A and c = 3.936 A. The calculated X-ray density is 5.51 g cm^{-3}. From single crystal photographs, the Laue symmetry of the compound is 4/mmm. Three additional symmetry unrelated reflections which are weak were revealed in hko layer photographs. These are probably superstructure type reflections. Relative intensity values and d-spacings from a powder pattern are listed.

23,595 TETRAGONAL PHASES OF THE GENERAL TYPE $10\ M_2O_5 \cdot 90\ M'_2O_5$ APPARENTLY ISOSTRUCTURAL WITH $Ta_2O_5 \cdot 2Nb_2O_5$ by J. Waring and R. Roth (Natl. Bur. Stand.); Acta Cryst., Vol. 17, pp. 455-456, Apr. 1964

An investigation has been made to determine whether the [β' $(Nb,V)_2O_5$] phase occurs in other binary systems. This phase can be indexed on the basis of a body-centered tetragonal unit cell with c = 3.821 A and a = 15.72 A. Data show that 10 mol per cent P_2O_5, As_2O_5 or V_2O_5 when added to 90 mol per cent of either Nb_2O_5 or Ta_2O_5 give X-ray diffraction patterns which can be indexed on a tetragonal cell. A tetragonal phase also forms for 10 mol per cent added to Nb_2O_5 but not when added to Ta_2O_5. Powder data appear to indicate that these phases are isostructural with the $Ta_2O_5 \cdot 2Nb_2O_5$ tetragonal cell, which has the lattice parameters c = 3.821 A and a = 15.75 A.

23,596 CRYSTALLOGRAPHIC DATA FOR PURE CRYSTALLINE SILVER FERRITE by W.J. Croft, N.C. Tombs and R.E. England (Sperry Rand Res. Ctr.); Acta Cryst., Vol. 17, p. 313, Mar. 1964

Single crystals of $AgFeO_2$ have been made by reacting Ag_2O and α-Fe_2O_3 under hydrothermal conditions in basic solutions. Thinner platelets were transparent and had a rich ruby red color in transmission; the mean value of the refractive index is greater than two. The measured density is 6.39 g. cm^{-3}. Diffractometer measurements, assuming hexagonal symmetry, yield the values a = 3.041 A and c = 18.55 A. The true symmetry is rhombohedral with the lattice constants for a primitive cell a_R = 6.427 A and α = 27°22'. $AgFeO_2$ crystals are stable up to about 700°C, at which temperature they decompose with loss of oxygen to yield metallic silver and α-Fe_2O_3.

23,597 IXIOLITE AND OTHER POLYMORPHIC TYPES OF $FeNbO_4$ by R.S. Roth and J.L. Waring (Natl. Bur. Stand.); Am. Mineralogist, Vol. 49, pp. 242-246, Mar.-Apr. 1964

$FeNbO_4$ was found to be trimorphic. The low temperature (ordered?) polymorph, stable from room temperature to about 1085°C, is monoclinic, space group $P2_1/a(C^5_{2h}$-No. 14) a = 5.001 A, b = 5.620 A, c = 4.653 A, β = 89.84° (90.16°). An orthorhombic ixiolite type structure is stable from about 1085°C to about 1380°C and a rutile type polymorph is stable from about 1380°C to the melting point at about 1475°C. The unit cell dimensions as well as the stoichiometry of the latter two polymorphs are dependent upon the heat treatment of the specimen. Other synthetic compounds which apparently have the ixiolite structure type are listed.

23,598 UNIT CELL AND SPACE GROUP OF THE CARBIDE Fe_2MoC by D. Dyson and K. Andrews (Swinden Labs.); Acta Cryst., Vol. 17, p. 459(L), Apr. 1964

It has been established that the carbide described by other researchers has the chemical composition Fe_2MoC. The carbide is obtainable only as a finely divided powder, and the unit cell and lattice parameters have been determined from interplanar spacings. Fe_2MoC has an orthorhombic unit cell with the following lattice parameters: a_0 = 16.27 A, b_0 = 10.03 A and c_0 = 11.32 A. The space group P222, (D_2^2-No. 17) is indicated. Confirmation of the unit cell has been obtained from electron-diffraction patterns.

23,599 REFINEMENT OF AN IRON CHROMIUM BORIDE WITH THE Mn_4B STRUCTURE by B. Brown and D. Beerntsen (Allis-Chalmers); Acta Cryst., Vol. 17, pp. 448-450, Apr. 1964

Crystals for X-ray investigation were prepared by vacuum melting equimolar amounts of chromium, iron, and boron yielding crystals of composition $Fe_{1.1}Cr_{0.9}B_{0.9}$. The orthorhombic cell dimensions from photographs are a = 14.57 A, b = 7.32 A and c = 4.22 A. The Mn_4B structure is in space group Fddd with 32 metal atoms on two sets of special positions, 16(e) and 16(f). Boron atoms are on a second set of 16(e) positions. No ordering is indicated for the metal atom positions of the experimental composition. Interatomic distances and angles are tabulated. The M(f) atoms are located at the vertices of hexagons whose plane is parallel to (100) while the M(e) atoms are located on hexagons parallel to (011) and $(01\bar{1})$ which include one boron atom.

23,600 NEW PHASES IN THE MANGANESE-SILICON AND IRON-MANGANESE-SILICON SYSTEMS by K.P. Gupta (Indian Inst. Tech., India); Trans. Met. Soc. AIME, Vol. 230, pp. 253-254(L), Feb. 1964

Two ternary systems, Fe-Mn-Si and Co-Mn-Si with low iron and cobalt concentrations (< 7 at.% Fe or Co) have been examined to detect occurrence of phases with complex crystal structure. In the Fe-Mn-Si system, a new ternary phase was found at 1000°C between the β-Mn and the Mn_3Si phase regions. This new phase, designated as the κ-phase, was found to occupy a narrow region about 1 at.% in width and extending from $Fe_{6.0}Mn_{74.5}Si_{19.5}$ to $Fe_{0.8}Mn_{80.2}Si_{19.0}$. Another new phase, designated as the ν-phase in the Mn-Si binary system, has also been reported. These two phases are thought to have been formed directly from the liquid state. Preliminary work on the powder pattern data of the κ-phase ($Fe_{4.0}Mn_{77.0}Si_{19.0}$) and the ν-phase ($Mn_{81.5}Si_{18.5}$) has indicated difficulty in complete indexing of the above systems on the basis of a cubic, hexagonal or tetragonal unit cell. Work done on the Co-Mn-Si system indicates that cobalt does not stabilize any ternary phase in the Co-Mn-Si system at these low concentrations of cobalt.

Crystal Structure of Ga-Nb Oxides - See 23,886

23,601 CRITICAL ANGLE IN THE UNIT CELL OF Bi_2Te_3 by H.H. Soonpaa (Honeywell Res. Ctr.); Bull. Am. Phys. Soc., Vol. 9, p. 279(A), Mar. 1964

The reciprocal lattice of a rhombohedral crystal is defined by angle α between any two basis vectors, or the c/a ratio in hexagonal notation. Only one c/a ratio $(c/a)^*$ can yield a structure in which the (122) plane passes through the (333) reciprocal lattice point. $(c/a)^* = 195/4^{1/2} = 6.98212 \cdots$; $\alpha^* = 24°4'14''$. Stoichiometric Bi_2Te_3 is p-type with $c/a < (c/a)^*$, in intrinsic Bi_2Te_3 $c/a = (c/a)^*$, and in n-type Bi_2Te_3 $c/a > (c/a)^*$. n-type material can be made by increasing c/a as a function of temperature [$c/a = (c/a)^*$ at 250°C], by adding Te, and by forming solid solutions with Bi_2S_3, Bi_2Se_3, Sb_2Te_3, and In_2Te_3. Compression along the c-axis ought to change n-type Bi_2Te_3 into p-type. To observe this effect before plastic deformation, one needs n-type material with $c/a <$ 0.06 per cent above $(c/a)^*$. For explaining the transport phenomena in Bi_2Te_3, one may need a large zone bounded by (122) planes because (1) $(c/a)^*$ exists, (2) (122) planes are tilted at the same angle as the energy ellipsoids in p-type Bi_2Te_3, and (3) (122) lines are the most intense ones in the X-ray diffraction pattern of Bi_2Te_3.

23,602 GROWTH OF LATTICE PARAMETERS OF HEXAGONAL ZnSe SINGLE CRYSTALS by F.L. Chan and Y.S. Park (Aerospace Res. Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 296(A), Mar. 1964

Single-crystal-rotation photographs of needlelike crystals grown by the sublimation method have revealed a perfect hexagonal growth pattern. Lattice parameters are obtained by analyzing the reciprocal lattice spots produced by Cu $K\alpha_1$ and Cu $K\alpha_2$ on the backreflection region of the cylindrical camera. These preliminary values of the lattice parameters are found to be a_0 = 4.003 and c_0 = 6.540 A. The charge of ZnSe powder is heated to about 1350°C in an argon atmosphere in a quartz tube. The flow of gas is maintained at 3.5 ft^3/h. In the region of about 1000°C, many needlelike crystals are formed on the walls of the quartz tube.

23,603 X-RAY DIFFRACTION STUDY OF COPPER AT HIGH TEMPERATURES by G.B. Mitra and S.K. Mitra (Indian Inst. Tech., Kharagpur); Indian J. Phys., Vol. 37, pp. 462-472, Sept. 1963

Spectroscopically pure copper has been cold worked by drawing it in the form of a wire and annealed at 500°C for about eight hours until equilibrium conditions were achieved. X-ray diffraction photographs of the sample at various high temperatures were taken. The lattice parameters as obtained from the photographs gave a nonlinear plot against temperature. The plot of the reciprocal of the volume expansion against the reciprocal of the product of the absolute temperature and the Debye function for energy at that temperature was found to be nonlinear. Similar results have been obtained by analyzing the data due to Nix and MacNair. An exponential form of Gruneisen equation has been shown to explain all the above results.

23,604 LATTICE PARAMETERS OF THE ALPHA PHASE IN COPPER-SILICON-ZINC ALLOYS by H. Pops (Mellon Inst.); Trans. Met. Soc. AIME, Vol. 230, pp. 267-268(L), Feb. 1964

Lattice parameters of the fcc α-phase alloys in copper-silicon-zinc ternary system at a constant electron concentration (c/a = 1.30) and also at a constant zinc content have been determined, with a view to detecting the occurrence of any interaction between solute atoms within the primary solid solution range. This study has indicated that there is no appreciable interaction between the solute atoms since no anomalous lattice spacings were observed.

23,605 AN X-RAY POWDER INVESTIGATION OF ORDERED Au_3Mn by D. Morris and J. Hughes (U. Coll., North Wales); Acta Cryst., Vol. 17, pp. 209-211(L), Feb. 1964

The fundamental cell dimensions of ordered Au_3Mn and the a'' phase (~21 to 22.2 at.% Mn) have been determined by X-ray powder photographs and diffractometer measurements. The fundamental cell of a'' is orthorhombic and the dimensions at 22°C for alloy 21.7 at.% Mn are: a = 4.081 A, b = 4.059 A, and c = 4.038 A. A tetragonal fundamental cell is deduced for ordered Au_3Mn with the fundamental cell dimensions a = 4.041 A, c = 4.064 A and c/a = 1.005.

23,606 LATTICE PARAMETERS AND EXPANSION COEFFICIENTS OF FeS_2 (NATURAL AND SYNTHETIC), AND OF CoS_2 by M.E. Straumanis, G.C. Amstutz and S. Chan (Missouri School of Mines and Met.); Am. Mineralogist, Vol. 49, pp. 206-212, Jan.-Feb. 1964

Precision lattice parameter measurements have been made on natural FeS_2 and CoS_2 as well as on synthetic FeS_2 in the temperature range 10 to 65°C. The expansion coefficients for these pyrites were calculated and lattice parameter measurements were normalized to 25°C. Crystals of the synthetic pyrite may have a slightly larger lattice constant than that of the natural mineral. No relationship is apparent between crystal habit and the lattice parameter. Reported values are:

	Synthetic FeS_2	Natural FeS_2	Natural CoS_2
$\alpha(deg^{-1})$	9.65×10^{-6}	9.25×10^{-6}	12.89×10^{-6}
a_{25}(A)	5.4189	5.41741	5.5343

23,607 THE EFFECT OF ALUMINIUM ON THE LATTICE PARAMETERS OF TIN RICH TIN-CADMIUM PHASES by A.J. Perry and H.J. Bray (Manchester U); Acta Met., Vol. 12, pp. 116-117(L), Jan. 1964

Discrepancies in the interpretation of lattice parameter variations in tin rich primary solid solutions in terms of interaction between Brillouin zones and Fermi surfaces of tin are discussed. From the data, the views of Lee and Raynor that in tin rich primary solid solutions, solutes of valency less than four (cadmium) increase the axial ratio of tetragonal tin are confirmed. In addition, it is also shown that solutions of aluminum in the hexagonal β phase cause a contraction of the a-axis without affecting the c-axis, leading thereby to an increased axial ratio relative to the binary phase.

23,608 THE LATTICE SPACING RELATIONSHIPS IN TERNARY CLOSE-PACKED HEXAGONAL SILVER-TIN-CADMIUM ALLOYS by B. Henderson (AE Res. Estab., Harwell); Acta Met., Vol. 12, pp. 377-382, Apr. 1964

The lattice spacings of twenty-two alloys of the hcp ζ-phase of the silver-tin-cadmium ternary system have been measured by X-ray powder photography. It is shown that the axial ratio of the ζ-phase is constant at a constant electron concentration of 1.40, despite variation in the a and c lattice spacings. At constant electron/atom ratios of 1.45, 1.50 and 1.55, however, the axial ratios of the ζ-phase alloys of the same electron concentrations are not constant; this behavior is contrary to that observed for ternary copper-base ζ-phases and for the ζ-phase of the gold-tin-cadmium system. These phenomena are interpreted in terms of the interactions between the Fermi surface and the faces of the first Brillouin zone for the hcp structure, and the possible effects of the solute elements on the band gaps across the zone faces are discussed.

23,609 STRUCTURE OF ELECTROLESS COBALT FILMS by R. Risher and D. Koopman (Natl. Cash. Reg.); J. Electrochem. Soc., Vol. 3, Part 1, pp. 263-264(L), Feb. 1964

The crystal structure and preferred orientation of cobalt films prepared by chemical (electroless) deposition are described. Such films deposited on Mylar are found to have a hcp structure and are microcrystalline with $10\bar{1}0$ orientation. The degree of orientation and grain size is determined by the hypophosphite ion concentration, at least when the cobalt ion concentration is constant. Cobalt films are amorphous when prepared at high hypophosphite ion concentrations and crystalline when prepared at low hypophosphite ion concentration. Electron diffraction studies on surface layers of films reveal that the structure of the surface is similar to that of the bulk determined by standard X-ray technique.

23,610 STRUCTURE OF ORIENTED, VAPOR-DEPOSITED GaAs FILMS, STUDIED BY ELECTRON DIFFRACTION by E.K. Muller (Philco Sci. Lab.); J. Appl. Phys., Vol. 35, pp. 580-585, Mar. 1964

Gallium arsenide films deposited on germanium surfaces of the types (111), (110), and (100) by flash evaporation in vacuum have been investigated by electron diffraction. The substrate temperatures ranged from 300° to 670°C, the films varied from 0.4 to 4μ in thickness, the deposit rates from 2 to 30 A/sec. The evaporator was kept at 1450°C. For deposition temperatures above 300°C the films showed extensive orientation effects on the single crystal germanium. On the (111) and (100) surfaces, epitaxy free of twinning was obtained for substrate temperatures above 600°C. For lower temperatures the electron diffraction patterns reveal stacking faults along the (111) planes of the deposits, leading to twin spots and interference lines, and even to a change from the cubic zinc blende to the hexagonal wurtzite structure.

23,611 CRYSTAL STRUCTURE OF THIN FILMS OF CADMIUM SULFIDE AS AFFECTED BY DEPOSITION CONDITIONS by K.V. Shalimova, A.F. Andrushko, V.A. Dmitriev and L.P. Pavlov (Moscow Power Inst.); Soviet Phys.-Cryst., Vol. 8, pp. 618-620, Mar.-Apr. 1964

A study of thin films of CdS formed by evaporation of the powder onto glass is reported. It is found that the structure is of the wurtzite type if the base is above 200-250°C. Between 100-120 and 200-250°C, both the cubic and hexagonal phases exist in the films. At lower temperatures, the cubic phase has not been found, while the hexagonal phase contains many defects. The films are always textured; the orientation is governed by the temperature of the base and by the pressure during the evaporation.

23,612 ELECTRON DIFFRACTION AND X-RAY PHOTOGRAPHIC INVESTIGATION OF OXIDE FILMS ON NIOBIUM by I.I. Korobkov, B.N. Revyakin, and C. Khe-Min; Trans. from Soviet Res. in Prod. and Phys. Met. of Pure Metals, Vol. 10, pp. 64-78, Jan. 1964; STAR, Vol. 2, p. 607(A), Mar. 8, 1964 JPRS-22697; OTS-64-21263; $3.00

The phase composition of oxides formed on niobium after oxidation in oxygen at a pressure of 150 mm/Hg in the temperature range between 400° and 1100°C has been investigated using electron diffraction and X-ray photographic techniques. The results show a more or less pronounced difference in the structure of the oxide films firmly bonded to the metal as compared to niobium oxides which have already flaked off the specimen. A mixture of the alpha and beta phases of Nb_2O_5 was observed in the oxide films formed in the temperature range 700° to 900°C. As the temperature is increased above this range, the amount of alpha phase Nb_2O_5 in the film decreases and the amount of beta-Nb_2O_5 increases.

23,613 ELECTRON DIFFRACTION DATA ON NEW COMPOUNDS IN THE SYSTEM PLATINUM-ALUMINUM by J.J. Comer (Sperry Rand); Acta Cryst., Vol. 17, pp. 444-445(L), Apr. 1964

Thin films of platinum and aluminum have been examined by electron microscopy and electron diffraction while heated in the electron microscope. Compositions studied were 50/50 and 78/22 wt. per cent platinum-aluminum. By varying the heating rate of these films, the compounds PtAl, $PtAl_2$, Pt_3Al, and Pt_5Al_3 were observed. Three additional compounds were observed: an fcc compound with unit cell dimension a = 4.10 A, a hexagonal compound with a = 4.22 a, c = 5.17 A, c/a = 1.225, and an orthorhombic compound with a = 9.79 A, b = 11.28 A, and c = 6.58 A. The hexagonal compound appears to be isostructural with Pt_2Ga_3 with probable space group $P\bar{3}n1$ (D^3_{3d}).

CRYSTAL IMPERFECTIONS

23,614 A COMPARISON OF X-RAY DIFFRACTION METHODS IN THE STUDY OF IMPERFECTIONS by R.H. Herz, E. Pitts and G.C. Terry (Kodak Res. Labs. Ltd., England); Acta Cryst., Vol. 17, pp. 265-271, Mar. 1964

Two groups of X-ray diffraction methods are used to study the imperfections present in the small silver halide crystals of photographic emulsions. One group reveals the possible existence of sub-units within the crystals. There is an unexplained discrepancy between the results for the (200) and (220) planes. A new experimental and theoretical approach has made possible the separate evaluation of misalignment and distortion within the grains. The method is a useful extension of existing techniques, and yields values which are also in agreement with results from other methods. These and the previous observations indicate the existence of substructures within the grains.

23,615 ENERGY DEPENDENCE OF NEUTRON DAMAGE IN SILICON — THEORETICAL by H.J. Stein (Sandia Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 288(A), Mar. 1964

The total cross-section information on silicon and differential cross-section data from magnesium and aluminum have been used to predict the neutron energy dependence for defect production in silicon for an energy range from 0.6 to 14 Mev. The predicted defect-production rate increases significantly less than linearly with energy. The ionization-energy losses by energetic silicon atoms are not known, but a model proposed by Lindhard and Nielsen has been used for an estimate of the energy loss by ionization. Applying this model further reduces the predicted energy dependence. The observed energy dependence is intermediate between the predictions with and without the correction for the ionization loss.

23,616 RELATIONSHIP OF THE NUMBER OF DEFECTS IN SINGLE CRYSTALS TO THE DIRECTION OF IRRADIATION by M.V. Fedulov; Trans. from Fiz. Metal. i Metalloved, Vol. 13, pp. 6-17, Feb. 1962; STAR, Vol. 2, p. 351(A), Feb. 8, 1964 JPRS-17613; OTS-63-21122, $0.75

The problem of the relationship of the number of defects in single crystals of the direction of irradiation with electrons and gamma quanta near the threshold

is considered. Approximation formulas are derived, and calculations are carried out which show considerable probability of the formation of a Frenkel pair, by an electron, during angular asymmetric irradiation of a single copper crystal.

23,617 RADIATION DEFECTS IN CADMIUM SULFIDE CRYSTALS by O.R. Niyazova and M.A. Kaneev (Acad. Sci. Uzbek SSR); Soviet Phys.-Solid State, Vol. 5, pp. 1997-1999(L), Mar. 1964

An investigation of the process of formation of defects in cadmium sulfide crystals is reported. It is found that beginning with a dose of $\approx 10^8$ R, dark spots appear on the surface, increasing with the absorbed dose. These spots are shown to be related to the points of emergence of dislocations on the surface. It is concluded that the most likely mechanism of the formation of radiation defects in CdS is the radiative decomposition in the interior of the sample with the products diffusing along the dislocation lines to the surface.

23,618 MONTE CARLO DEFECT-ANNEALING CALCULATIONS by N.R. Baumgardt and J.R. Beeler, Jr. (GE); Bull. Am. Phys. Soc., Vol. 9, p. 294(A), Mar. 1964

Monodefect-annealing by association was computed analytically and by an analog Monte Carlo method for a fcc system. An initial defect concentration of 2×10^{-4} was assumed. The analytical calculations were based on the distribution S(n) of distinct sites visited by a defect in n nearest-neighbor jumps. S(n) was computed in a separate Monte Carlo study. When concentration fluctuations were ignored analytically (average concentration approach), the Monte Carlo initial annealing rate was 6.7 times the analytical result. Approximate agreement was obtained by randomly distributing the initial defect population among equal subvolumes in the analytical treatment. The Monte Carlo/analytical-initial annealing rate ratio was reduced to 1.5 by using 5000-site subvolumes. After 500 jumps, the annealing rates given by the average concentration approach and the Monte Carlo calculation were identical, but the former overpredicted the monodefect population by 23 per cent. This error increases with n. Concentration fluctuations should be considered in computing the initial annealing rate and defect population for high-temperature quench and irradiated specimens.

23,619 OBSERVATION OF IRRADIATION INDUCED DEFECTS IN TUNGSTEN BY INTERNAL-FRICTION MEASUREMENTS by J.A. De Carlo and J.R. Townsend (U. Pittsburgh); Bull. Am. Phys. Soc., Vol. 9, p. 397(A), Apr. 1964

After 14 Mev deuteron irradiation at 80°K, 2 reproducible but transient peaks, I and II, are observed in the internal-friction vs temperature curve for tungsten polycrystalline wires (200 ppm metallic-impurity concentration). At 1 kc, I is found at 100°K and II at 190°K. Frequency-dependent measurements of peak temperatures show the relation $f_{peak} = 10^{y} e^{-Em/kT}$. Present results are $E_m{}^{I} = 0.17 \pm 0.03$ ev, $y^{I} = 12 \pm 1$ and $E_m{}^{II} = 0.40 \pm 0.04$ ev, $y^{II} = 13.5 \pm 1.0$. The isothermal decay of peak II shows 1st order annealing kinetics with an activation energy of 0.45 ± 0.05 ev. About 10^6 jumps are taken before disappearing. Dependence on deuteron flux shows that both peak heights saturate at approximately 500 ppm defect concentration. Neither high-temperature anneals nor iron-doping before irradiation affects the peak characteristics for polycrystalline wires. Irradiation of high-purity-tungsten single crystals (5 ppm metallic-impurity concentration, both unworked and heavily cold-worked) produced neither of the peaks. Thus, it is believed that an irradiation-induced defect is being observed in its motion around an impurity atom at which it is temporarily trapped.

Irradiation Induced Defects in KBr - See 23,914

23,620 GRAPHITE DEFECTS OBSERVED BY ELECTRON MICROSCOPY by G. Bonfiglioli and A. Mojoni (Ist. Elettrotec. Naz. Galileo Ferraris, Torin); J. Appl. Phys., Vol. 35, pp. 683-685, Mar. 1964

Structural defects of natural graphite are characterized by Newton-ring-like electron microscopic contrast. Pictures are given, evidencing their aspect, their peculiar distribution (often corresponding to linear alignment), and their behavior at high temperatures. A discussion is presented concerning related theoretical and experimental results of other authors and in particular the relationship of these defects to radiation damage.

POINT DEFECTS (VACANCIES AND INTERSTITIALS)

23,621 THERMAL EQUILIBRIUM KINETICS OF INTERACTING POINT DEFECTS by C.P. Flynn (U. Illinois); Phys. Rev., Vol. 134A, pp. A241-246, Apr. 6, 1964

The local kinetics of an interacting defect species is treated on the assumption that local thermal equilibrium prevails, and a thermal equilibrium diffusion coefficient appropriate to any locality is derived in its general form. The annealing of an interacting defect species to sinks in the lattice is then shown to be identical with that of noninteracting defects having a diffusion coefficient

$$D_{eff} = \Sigma_{n\alpha}\, nc_{n\alpha}{}^{0} D_{n\alpha} / \Sigma_{n\alpha}\, nc_{n\alpha}{}^{0},$$

where $c_{n\alpha}{}^{0}$ is the concentration far from the sink of an nth order cluster of ty α, and $D_{n\alpha}$ is its diffusion coefficient. The importance of the particular case when $c_{n\alpha}{}^{0}$ achieves the thermal equilibrium value $c_{n\alpha}{}^{t}$, is noted, and the range of applicability of this diffusion coefficient is discussed.

23,622 OPERATOR APPROACH TO THE ELECTRONIC PROPERTIES OF DEFECTS by J. Rubio-Bernal, F. Garcia-Moliner, and R. Thomson (U. Illinois); Bull. Am. Phys. Soc., Vol. 8, p. 276(A), Mar. 1964

The solution of the point-imperfection problem due to Clogston is generalized by means of the resolvent to obtain the density of states of the problem in terms of a secular determinant. The argument of the determinant provides all the necessary information regarding virtual- as well as real-bound states, and is related, through an operator analysis, to the weighted sum of the phase shifts in scattering theory.

23,623 PRESSURE AND TEMPERATURE DEPENDENCE OF DEFECT FORMATION AND MIGRATION VOLUMES by L.A. Girifalco (U. Pennsylvania); Acta Met., Vol. 12, pp. 112-113(L), Jan. 1964

Equations are presented for analyzing high pressure experimental data in order to estimate the effect of point defects on the compressibility and thermal expansion coefficients of a crystal. In the case of sodium, it is estimated that 1 per cent vacancy concentration would increase the coefficient of thermal expansion and compressibility by 4.8 per cent. However, the vacancy would have a greater effect on the compressibility in sodium than in fcc metals.

23,624 VACANCY CONCENTRATION AND DIFFUSION IN ORDER-DISORDER ALLOYS by L.A. Girifalco (U. Pennsylvania); J. Phys. Chem. Solids, Vol. 24, pp. 323-333, Mar. 1964

By means of the partition function formalism, the average vacancy concentration can be expressed as an expansion in the moments of the energy. Retaining only the first term in the expansion and expressing the energy in terms of nearest neighbor pairwise interactions is equivalent to a Bragg-Williams theory of vacancy concentration. It is found that both sub-lattices of a (50-50) AB alloy contain the same number of vacancies, and the probability that a site is vacant is given in the usual way by the Boltzmann factor containing a formation energy. This formation energy is an increasing quadratic function of the long-range order parameter. The average jump frequency can also be written as an expansion in moments, and the equivalent of the Bragg-Williams approximation leads to a migration energy that is also an increasing quadratic function of the long-range order. The average jump frequencies of the two types of atoms in a binary alloy differ in a manner determined by the interatomic energies at the saddle point and at the normal positions. If the diffusion coefficient is taken as proportional to the product of the average jump frequency and the average vacancy concentration, it is found that a plot of lnD vs 1/T must be corrected by a factor quadratic in the long-range order parameter in order to become linear. This is again equivalent to neglecting higher moments. An analysis of the experimental data for β-brass shows that the present theory is successful within the limits of experimental error.

23,625 MEASUREMENT OF EQUILIBRIUM VACANCY CONCENTRATIONS IN DILUTE ALUMINUM-SILVER ALLOYS by B.R. Beaman, R.W. Balluffi and R.O. Simmons (U. Illinois); Phys. Rev., Vol. 134A, pp. A532-542, Apr. 20, 1964

Measurements of the differential length expansions $(\Delta L'/L' - \Delta L^0/L^0)$ and differential X-ray lattice parameter expansions $(\Delta a'/a' - \Delta a^0/a^0)$ have been made on pure aluminum and two dilute aluminum base alloys containing 0.53 and 0.94 at.% silver during slow reversible heating and cooling between the solidus and the solubility limit temperature. Absolute differences between the equilibrium vacancy concentrations in each alloy and the pure metal were obtained from the relation

$$\Delta C_v = C_v' - C_v{}^{0} = 3(\Delta L'/L' - \Delta L^0/L^0) - 3(\Delta a'/a' - \Delta a^0/a^0).$$

Here, C_v is the equilibrium vacancy concentration and $\Delta L/L$ and $\Delta a/a$ are length and lattice parameter expansions. The prime and zero superscipts refer to the alloy and pure aluminum, respectively. These differential data serve to determine C_v'. The differential length and lattice parameter measurements yielded a relatively high precision in the determination of the extremely small differences involved. The addition of silver caused only small increases in the vacancy concentration. Values of ΔC_v equal to $(13 \pm 5) \times 10^{-5}$ and $(12 \pm 5) \times 10^{-5}$ were found for the 0.52 and 0.94 at.% silver alloys, respectively, at their solidus temperatures. These increments correspond to $\leq 23\%$ of the concentration in pure aluminum. The results for both alloys could be fitted to a simple first-order vacancy-solute atom binding model, where

$$\Delta C_v = 12 C_s C_v{}^{0} [\exp(-S_{vs}{}^{b}/k) \exp(E_{vs}{}^{b}/kT) - 1].$$

Here, C_s is the solute concentration, and the best value of the binding energy, $E_{vs}{}^{b}$, was found to 0.08 ev for an assumed binding entropy $S_{vs}{}^{b} = 0$.

3,626 QUENCHING AND ANNEALING OF ZONE-REFINED ALUMINUM y M. Doyama and J.S. Koehler (U. Illinois); Phys. Rev., Vol. 134A, pp. 522-529, Apr. 20, 1964

Detailed annealing studies have been done on quenched zone-refined aluminum. The research was undertaken to determine the migration energy of the divacancy E_M^2 and the binding energy of the divancancy B_2 in pure aluminum. It was found that $E_M^2 = 0.50 \pm 0.04$ ev and $B_2 = 0.17 \pm 0.05$ ev. Some discussion of the properties of larger vacancy clusters is given.

3,627 THE ANNEALING OF VACANCIES AND VACANCY AGGREGATES N QUENCHED GOLD, SILVER AND COPPER by L.M. Clarebrough, R.L. egall, M.H. Loretto and M.E. Hargreaves (CSIRO, U. Melbourne); Phil. Mag., Vol. 9, pp. 377-400, Mar. 1964

It is shown, using electrical resistance measurements and transmission electron microscopy, that the annealing behavior of copper quenched from high temperature is similar to that of silver, provided that care is taken in both cases to avoid contamination by oxygen. To achieve this, copper was quenched from an atmosphere of carbon monoxide. The results obtained under these conditions suggest that the divacancy is the principal defect retained in copper after quenching from high temperatures. The temperatures at which stacking-fault tetrahedra anneal out in silver and gold were studied by transmission microscopy. In silver, tetrahedra are stable up to at least 930°C. The stability of tetrahedra in gold depends on their size, being greater the larger the tetrahedra. Finally it has been shown that dislocation loops, not tetrahedra, predominate as the clustered vacancy defect in gold if, after quenching from high temperature to 0°C, the gold is rapidly unquenched to 100°C.

3,628 ANNEALING OF VACANCIES IN ALKALI HALIDES X-RAYED AT OW TEMPERATURES by N. Itoh, B.S.H. Royce and R. Smoluchowski (Princeton U.); Bull. Am. Phys. Soc., Vol. 9, p. 261(A), Mar. 1964

Negative-ion vacancies produced by X-rays in alkali halides at low temperatures can be observed either as the a band or the F band. The thermal annealing of these optical-absorption bands was studied. The a band formed at 6°K was almost completely annealed by warming up to 22°K through several annealing stages: 9° ~ 13°, 15° ~ 18.5°, and 18.5° ~ 22°K. Isothermal-annealing curves for the first two annealing stages fit a first order reaction, which indicates that they are due to annihilation to close pairs. Activation energies obtained from isochronal and isothermal annealing experiments did not agree too well, the latter giving lower values. The activation energies and pre-exponential factors are 0.010 ± 0.004 ev and $10 \sim 10^4$ sec^{-1} and 0.023 ± 0.005 ev and $10^3 \sim 10^6$ sec^{-1} for the first and second annealing stages, respectively. The pre-exponential factors are much smaller than those usually expected for the close-pair annihilation. The F band was reduced only about 10 per cent in this temperature range.

23,629 ON THE NUCLEATION OF VACANCY CLUSTERS IN GOLD by T. Mori and M. Meshii (Northwestern U.); Acta Met., Vol. 12, pp. 104-106(L), Jan. 1964

The nucleation of vacancy clusters has been studied by the transmission electron microscopic technique in quenched gold. The importance of aging temperature and pre-aging as significant factors in determining the final configuration of tetrahedral stacking faults is established. Below 140°C, nucleation process is found to take place in this system. As a transport mechanism, jump of divacancies is preferred to migration of single vacancies for gold.

23,630 NUCLEATION OF SURFACE PITS BY THE CONDENSATION OF VACANCIES by J.R. Jasperse and P.E. Doherty (AD Little); Phil. Mag., Vol. 9, pp. 635-644, Apr. 1964

Small surface pits were observed to form on electropolished (111) surfaces of aluminum single crystals during cooling from elevated temperatures. The formation of these pits was attributed to the condensation of vacancies from the supersaturation produced during cooling at the points of intersection of dislocations with the surface. A finite temperature drop, ΔT, which was a function of the holding temperature, T_h, was required to nucleate the pits. The principles of statistical mechanics when applied to vacancy clustering led to an equation which quantitatively predicted ΔT as a function of T_h. The temperature dependence of the nucleation phenomenon was experimentally measured and found to be consistent with the theoretical predictions. The experimental results led to a corrected value of 1.8×10^{-5} ergs/cm (0.3 ev/plane) for the average dislocation core energy per unit length in aluminum.

23,631 ENERGY OF FORMATION AND MIGRATION OF AN INTERSTITIAL AND A VACANCY IN DIAMOND, SILICON, AND GERMANIUM by K.H. Brennemann (U. Illinois); Bull. Am. Phys. Soc., Vol. 9, p. 298(A), Mar. 1964

A new method is proposed for calculating from first principles the energy of formation and migration of a vacancy or an interstitial in covalent crystals. The formation energy of a lattice-point imperfection is given by the change in the electrostatic energy of the system of ions plus the change in energy of the system of valence electrons owing to their redistribution caused by the point defect. The redistribution of the valence electrons is determined from a pseudo crystal potential, which results from orthogonalizing the valence-electron wavefunctions to the crystal-core wavefunctions. The scattering of the valence electrons by the pseudo crystal potential is determined by using the t-matrix approximation. The formation energy of an interstitial in diamond, silicon, or germanium turns out to be 5.31, 3.06, and 2.87 ev, respectively. For the migration energy of the interstitial, one gets 0.87, 0.51, and 0.46 ev for diamond, silicon, and germanium, respectively. The vacancy-formation energy is 3.68, 2.13, 1.91 ev and the migration energy is 1.85, 1.09, and 0.98 ev in diamond, silicon, and germanium, respectively.

23,632 MODEL FOR STAGE II DEFECTS IN InSb by F.H. Eisen (NA Aviation); Bull. Am. Phys. Soc., Vol. 9, p. 290(A), Mar. 1964

The data for stage II recovery in InSb indicate that there are two slightly different close interstitial-vacancy pair configurations that annihilate in this stage. These are produced in a ratio of about two to one at 1.0 Mev, the predominant one having a first-order decay constant equal to about 1/3 that of the faster decaying, but less numerous, pair. A comparison of damage-production rate when a (111) face is exposed to the electron beam with that when a $(\bar{1}\bar{1}\bar{1})$ face is exposed indicates that both close pairs are produced by the displacement of an indium atom. The recovery-activation energy for the two pairs is almost the same, indicating that essentially the same rate-limiting step must be involved in the annihilation of either pair. This makes it difficult to see how interstitial motion could account for the rate-limiting step, since different barriers to motion would probably be encountered by the two different interstitials. A model is presented in which the rate-limiting step in the defect annihilation is the motion of an indium vacancy. Semiquantitative agreement with the relative numbers and decay rates of the pairs is obtained.

23,633 RELAXATION AND ACTIVATION ENERGIES FOR AN INTERSTITIAL NEUTRAL DEFECT IN AN ALKALI HALIDE LATTICE. Part II by R.D. Hatcher and G.J. Dienes (Brookhaven Lab.); Phys. Rev., Vol. 134A, pp. A214-226, Apr. 6, 1964

The distortion around and the relaxation energy for a Cl^0 interstitial atom in a NaCl lattice has been obtained for various positions of the Cl^0 by a method involving the exact calculation of electrostatic, polarization, dipole-dipole, and repulsive energies. The relaxation of from 14 to 23 neighboring ions has been taken into account, using up to nine independent parameters, in minimizing the energy relative to the perfect lattice. The cube-center and cube-diagonal positions were always found to be stable relative to the face-center and face-diagonal positions. There are two energy minima of almost the same value along the body diagonal, one in the center of the cube and one in which the Cl^0 and Cl^- are located on either side of a normal Cl^- lattice position. These two minima are separated by a potential barrier of about 0.2 ev. The energy differences for the various configurations along the face diagonal are small with the face center the position of lowest energy. The face-center position is metastable with respect to the body-center position by about 0.03 ev. The energy difference between the body-center and face-center positions is 0.44 ev, giving an activation energy along this line of motion of 0.47 ev.

23,634 INTERSTITIALS AND VACANCIES IN α-IRON by R.A. Johnson (Brookhaven Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 295(A), Mar. 1964

The migration energies and atomic configurations for interstitials and vacancies in α-iron have been calculated with a classical model similar to that used by Johnson and Brown. About 530 atoms surrounding the defect were treated as individual particles, while the remainder of the crystal was treated as an elastic continuum with atoms imbedded in it. A 2-body central force was devised that matches the elastic moduli, is sharply repulsive at close separation, and goes to 0 midway between the 2nd- and 3rd-neighboring atoms. Calculated activation energies for motion of mono- and di-interstitials and mono- and di-vacancies are 0.33, 0.18, 0.68, and 0.66 ev, respectively, and binding energies of di-interstitials and divacancies are 1.08 and 0.20 ev, respectively. The stable interstitial is a "split" configuration in which 2 atoms are symmetrically split in a <110> direction about a vacant normal lattice site. Di-interstitial and di-vacancy configurations are discussed, as well as the migration paths for the various defects.

23,635 DETERMINATION OF THE MIGRATION ENERGY OF INTERSTITIAL ATOMS IN GOLD by J.A. Venables and R.W. Balluffi (U. Illinois); Bull. Am. Phys. Soc., Vol. 9, p. 295(A), Mar. 1964

The interstitial migration energy in gold has been determined directly using low-energy ion bombardment inside an electron microscope. Quenched foils of gold containing vacancy tetrahedra were bombarded between -130° and 30°C with 200 ev Au^+ ions, which produce interstitials about 100 A below the bombarded surface by replacement collision sequences. Above 10°C, the tetrahedra disappeared, but below -10°C most of them remained in the foil, indicating that interstitials do not diffuse appreciably below this temperature. Many of the tetrahedra still present after bombardment below -10°C disappeared on warming to about 0°C, i.e., by interstitials diffusing to the tetrahedra. The bombardment also produced sub-surface interstitial clusters everywhere except

in a zone at the thin specimen edge. This denuded zone extended to progressively thicker regions as the bombardment temperature was raised above 0°C, indicating that the interstitial concentration is reduced by diffusion to the back foil surface. An analysis of these phenomena gave values of the interstitial diffusion coefficient (1.7×10^{-14} cm^2 sec^{-1} at 300°K), migration energy (0.75 ± 0.06 ev), and the binding energy of very small interstitial clusters (< 0.1 ev per interstitial).

Formation of Vacancies in Cu_3Au - See 23,556

23,636 PRODUCTION AND DESTRUCTION OF F AND M CENTERS BY X-RAYS IN ALKALI HALIDES AT LOW TEMPERATURES by R.F. Wallis and B.J. Faraday (U.S. Naval Res. Lab.); Phys. Rev., Vol. 133A, pp. A1360-1364, Mar. 2, 1964

An approximate theoretical analysis is given of the production and destruction of F and M centers by X-rays in alkali halides at low temperatures. Kinetic equations describing the time rates of change of F- and M-center concentrations are formulated. Conditions on the kinetic coefficients are established for the validity of the square-law relation between F- and M-center concentrations when the concentration of F centers is not a linear function of X-ray irradiation time. Two mechanisms which lead to a saturation of F-center production are analyzed in some detail. A comparison of theoretical and experimental results leads to information concerning the processes involved in the production and destruction of color centers by X-rays.

23,637 F-CENTER PRODUCTION EFFICIENCIES AT LIQUID-HELIUM TEMPERATURE by V.H. Ritz (U.S. Naval Res. Lab.); Phys. Rev., Vol. 133A, pp. A1452-1470, Mar. 2, 1964

The efficiencies for F-center production (ev/F center) have been measured at liquid-helium temperature for KBr, KCl, LiF, and NaCl irradiated with 2.0 Mev electrons and with X-rays. The F-center production efficiencies for easily colored alkali halides are typically of the order of 5000 ev/F center for irradiation, decrease to about 1800 ev/F center for 50 kv X-ray irradiation and then rise again to about 5000 ev/F center for 10 kv X-ray irradiation. NaCl follows the same general trend but is about six times as hard to color. Irradiations of KBr with X-rays whose energies are just above or just below the K absorption edge of bromine indicate that the K edge does not play a dominant role in the coloration process. Various quantitative and qualitative arguments are presented which indicate that inner shell ionization does not adequately account for either the magnitude of the observed vacancy production or the direction of its energy dependence. A correlation is made between the coloration efficiency and the ionization density along the tracks of the electrons generated by irradiation. It is concluded that mechanisms involving the single ionization of two adjacent halide ions are a more probable cause of the coloration than mechanisms involving either the single ionization of one halide ion or the multiple ionization of one halide ion.

23,638 FORMATION AND BLEACHING OF COLOR CENTERS IN NaN_3 by B.S. Miller (USAERDL, Fort Belvoir); J. Chem. Phys., Vol. 40, pp. 2371-2378, Apr. 15, 1964

Results of new experiments on low-temperature, photolytically colored sodium azide are presented. By use of a highly monochromatic light source, it has been found possible to bleach one component of the F_2^+ band and demonstrate the formation of F centers by the released electrons. Thermal bleaching experiments are described which illustrate the presence and lifetime of double anion vacancies. Decomposition of an excited azide ion at a vacancy is postulated as a necessary step in formation of double anion vacancies at low temperature.

23,639 DOSE-RATE EFFECTS IN THE COLORATION OF ALKALI HALIDES AT 80°K by F.E. Pretzel, J.L. Anderson and G.N. Krebs, Jr. (Los Alamos); Bull. Am. Phys. Soc., Vol. 9, p. 261(A), Mar. 1964

Coloration rates of alkali halides at 80°K were studied as a function of dose rate using "hard" and "soft" X-rays, and ultraviolet light from an unfiltered mercury lamp. For "hard" X-rays at low dose rates, coloration rates were proportional to the first power of the dose rate; but for "soft" X-rays at high dose rates, coloration rates were proportional to higher powers. These results can be explained for a Varley-type coloration mechanism initiated by adjacent halogen ionizations created either in the track of one energetic primary or in intersecting tracks. The second effect is important in regions of high-ionization density produced by a high flux of low-energy radiation. The lattice expansions of salts exposed to high-intensity β-irradiation show a high-order dependence on dose rate. Ultraviolet cannot produce more than one ionization per photon. Experiments on KI have demonstrated a high-power dependence on ultraviolet flux and that large concentrations of color centers can be produced. Ultraviolet and X-ray photons reinforce each other to increase the defect yield above the sum of the independent yields. The relative yield of a centers to F centers is higher for ultraviolet- than X-rays.

23,640 F-CENTER GROWTH KINETICS FOR X-IRRADIATED NaCl AND KCl by T. Mumaw, A. Raichie and D.A. Wiegand (Carnegie Inst. Tech.); Bull. Am. Phys. Soc., Vol. 9, p. 262(A), Mar. 1964

F-band growth curves for NaCl have been obtained that are similar to those reported previously for KCl. They show the same general intensity-dependent structure and the I^2 dependences of the slope of the later-stage linear region. In addition, the "saturation" level appears to be intensity-dependent. Growth curves obtained from plates of KCl subjected to plastic compressions either parallel or perpendicular to the plane of the plate, and for two intensities, show dependence on deformation direction. A dependence of the effect of deformation on intensity is also suggested. Deformations carried out after the growth curve is well into the plateau region produce abrupt increases in the rate of F-center generation upon resumption of irradiation, thus indicating vacancy generation during the deformation process. The dependence of F-center-formation kinetics in deformed samples on deformation geometry and intensity may be partially responsible for the apparent contradictions appearing in the literature. Samples were plates of approximately 1 mm thickness and were irradiated at room temperature by a ~240-kvp X-ray beam filtered by 1.6 mm Al and directed perpendicular to the plane of the plate.

23,641 TEMPERATURE DEPENDENCE OF VACANCY PRODUCTION BY X-RAYS IN POTASSIUM IODIDE by T.P.P. Hall, D. Pooley and P.T. Wedepohl (AE Res. Estab., Harwell); Proc. Phys. Soc., Vol. 83, pp. 635-643, Apr. 1964

The X-ray coloration of KI, in particular the growth of the F band, has been investigated at a series of temperatures below room temperature. It is found that the slow stage rate of growth of the F band, and the qualitative features of the absorption spectra of irradiated crystals, are sample dependent even at liquid helium temperature. The rate of growth of the F band is found to be very temperature dependent, showing a very rapid rise near 90°K and reaching a maximum between 90 and 195°K. This is explained in terms of a model based on the interaction of pairs of singly ionized anions.

23,642 GENERATION OF F CENTERS IN KBr WITH MONOCHROMATIC X-RAYS AT BROMINE K EDGE by J. Sharma and R. Smoluchowski (Princeton U.); Bull. Am. Phys. Soc., Vol. 9, p. 262(A), Mar. 1964

The generation of F centers in KBr as a function of the wavelength of X-rays has been studied on either side of the K edge at liquid-nitrogen, dry-ice, and room temperatures. At liquid-nitrogen temperature, more F centers are produced on the high-energy side than in the low-energy side of the K edge in the ratio of 9:8. (This is to be compared with earlier results for KCl, which gave a ratio of 3:2). Since the background coloration due to photoelectrons and to ionization in the higher levels is about the same on either side of the edge, the discontinuity is an evidence in support of the Varley mechanism of defect generation. The K-edge discontinuity becomes more pronounced as irradiation proceeds, because generation of new vacancies is required beyond the structure-sensitive range. The discontinuity does not show up at dry-ice and room temperatures because, with increasing temperature, the structure-sensitive coloration is known to become progressively more important.

23,643 EFFECT OF PLASTIC DEFORMATION ON EARLY-STAGE COLOR-CENTER FORMATION IN KCl by B.L. Damsky and B.S.H. Royce (Princeton U.); Bull. Am. Phys. Soc., Vol. 9, p. 262(A), Mar. 1964

Experiments are discussed in which the early stage of color-center formation has been interrupted by plastic deformation and the irradiation then continued on the deformed sample. From the form of the growth curves before and after deformation at various temperatures, it is concluded that the defects introduced by deformation are the same as those responsible for the first-stage coloration in undeformed crystals. Room-temperature growth curves for which the deformation was performed at liquid-nitrogen temperatures show an enhanced first stage after deformation. Annealing experiments on this additional coloration are discussed.

23,644 EFFECT OF Pb AS IMPURITY ON THE LATE-STAGE F-CENTER COLORATION OF ROOM-TEMPERATURE-IRRADIATED KCl CRYSTALS by W.A. Sibley, E. Sonder and C.T. Butler (Oak Ridge Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 262(A), Mar. 1964

It has been proposed that the large variations in the late-stage colorability (F-center introduction by ionizing radiation) for different samples of KCl may be due to trace impurities acting as electron-trapping or -recombination centers. In order to clarify the relation of electron-hole processes to coloring behavior, coloring curves were obtained for KCl crystals containing different amounts of $PbCl_2$ impurity. Pb ions clearly decrease the late-stage coloration rate; ~100 pmm completely suppresses the late stages. The effect on the F-center/M-center ratiation equilibrium is to shift it to greater M-center concentrations that would be expected if Pb^{2+} acted as a hole-trapping center at room temperature.

23,645 GROWTH AND ANNEALING OF F CENTERS IN γ-RAY-IRRADIATED KCl by S. Kalbitzer and P.W. Levy (Brookhaven Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 262(A), Mar. 1964

The coloring and annealing of the γ-ray-induced F centers in KCl has been

died by making absorption measurements while irradiating and heating. Sin- crystals of KCl 2 by 1 by 0.8 cm were irradiated in a 5000 r/h ^{60}Co source il the desired optical density (usually between 0.1 and 1) was reached and n annealed to about 200°C, which removes all coloring. Even after numer- irradiation and heating cycles, very nearly the original coloring and an- ling curves were obtained. From isothermal-heating studies, bimolecular ealing kinetics are obtained, describable by equations $(-dF/dt) = F\Sigma_i k_i V_i$ $F = V = \Sigma V_i$. F is F-center concentration and V_i is the concentration of the type of hole center having recombination coefficient k_i. From linear-heat- studies, using different crystals, several prominent annealing stages are arly resolved and additional minor stages indicated. Activation energies for prominent stages can be obtained. The linear-heating results agree well h the bimolecular behavior. At room temperature, at least two annealing nponents occur. Compressing prior to irradiation decreases the amplitude of and the other increase.

646 F-AGGREGATE COLOR CENTERS IN KCl by S. Schnatterly and W. Compton (U. Illinois); Bull. Am. Phys. Soc., Vol. 9, p. 262(A), Mar. 1964

equilibrium that is established between F and F-aggregate centers in KCl X-rays has been studied at room temperature. It was found that

$$N_R = K_R N_F N_M, \quad N_{N_2} = K_{N_2} N_F N_R, \text{ and } N_{N_1} = K_{N_1} N_M,$$

icating that R centers are composed of three F centers, N_2 centers are com- ed of four F centers, and N_1 centers are probably composed of two F cen- s. The deviation from linearity of the N_F^2 vs N_M curve is shown to arise m the presence of higher aggregate centers.

nealing of Defects in Rh - See 23,984

DISLOCATIONS

,647 KINETIC THEORY OF DISLOCATIONS by N.S. Akulov; Dislocation dies, pp. 8-15, Mar. 4, 1964, Trans. from Inzhenerno-Fiz Zh., Vol. 4, .2, pp. 70-76, 1961; STAR, Vol. 2, p. 104(A), Apr. 23, 1964 RS-23509; OTS-64-21709, $1.00

e kinetic theory of dislocations is developed, and equations are obtained for e calculation of dislocation density as a function of plastic deformation. Re- ionships are given for the decrement of internal friction as a function of stic deformation.

,648 THE SOLUTION OF CERTAIN KINETIC EQUATIONS IN THE THE- Y OF DISLOCATION by B.Ya. Lyubov; Soviet Studies in Dislocation Struc- e, pp. 34-41, Jan. 30, 1964, Trans. from Dokl. Akad. Nauk SSSR, Vol. 2, pp. 1092-1095, Oct. 1963 JPRS-22981; OTS-64-21430, $1.25 AR, Vol. 2, p. 915(A), Apr. 8, 1964

uations are developed that allow the use of kinetic equations in solving the oblem of the equilibrium positions of dislocations in metals under loads. For ample, the results can be utilized in analyzing the development, in time, plastic deformation caused by dislocations originally located close to the igin of the coordinate system x = 0.

,649 APPLICATION OF STATISTICAL THEORY OF DISLOCATIONS TO ERIVATION OF BASIC RELATIONSHIPS FOR STRENGTHENING CURVES by .S. Kaulov and A.K. Shukevich (Acad. Sci. Byeloruss. SSR); Investigation Dislocation Structures, pp. 1-6, Nov. 29, 1963, Trans. from Dokl. Akad. auk SSSR, Vol. 7, pp. 453-455, July 1963; STAR, Vol. 2, p. 503(A), Feb. , 1964 JPRS-22076; OTS-63-41255, $2.25

is shown that, within the framework of Akulov's statistical theory of disloca- ons, it is possible to obtain more general formulas for metal-strengthening rves; certain equations are presented which occur as special cases. It is also own that for small deformation equations these expressions give identical re- tionships, and the mechanism which is the basis of the processes described by e equations is discussed.

3,650 DISLOCATIONS — THEIR ORIGIN AND MULTIPLICATION by G. homas; J. Metals, Vol. 16, pp. 365-369, Apr. 1964

mpurity particles, grain boundaries, and localized nonequilibrium vacancy oncentrations are discussed as the most probable sites of dislocation nuclea- on in crystals. Thermal stresses during cooling may be responsible for operat- g such sources. The operation of grain-boundary sources is indicated to be ne of the significant factors controlling the effect of grain size upon strength.

3,651 EFFECTS OF SURFACE STRESS RELAXATION ON THE ELECTRON MI- ROSCOPE IMAGES OF DISLOCATIONS NORMAL TO THIN METAL FOILS y W.J. Tunstall, P.B. Hirsch and J. Steeds (Cavendish Lab., Cambridge); hil. Mag., Vol. 9, pp. 99-119, Jan. 1964

The two-beam dynamical theory of Howie and Whelan is used to calculate the electron microscope image contrast from dislocations normal to a thin crystal and parallel to the direction of the incident electron beam. Bending of the lattice planes due to surface relaxation and change in lattice parameter are taken into account. Strong contrast in the form of black-white spots is predicted for dislocations with a screw component, while contrast from pure edge dislocations is expected to be very weak. Observations on platinum and copper are in good agreement with the predictions for dislocations with a screw component. It is possible from these contrast effects to determine the sense of the screw component of the dislocation.

23,652 AN ELECTRON MICROSCOPE STUDY OF DISLOCATION ARRANGEMENTS IN FATIGUED Al + 1% Mg CRYSTALS by J.T. McGrath and G.W.J. Waldron (Dept. Mines and Tech. Surveys, Ottawa); Phil. Mag., Vol. 9, pp. 249-259, Feb. 1964

A study has been made by transmission electron microscopy of aluminum + 1% magnesium crystals fatigued in plane bending. A specimen preparation technique has been used that allows selected areas of a fatigued surface to be examined. It is shown that a surface sub-structure exists, which is associated with 'persistent markings' observed optically. Electron micrographs of areas between striations show bands of loops and line dislocations similar to those observed in copper and other face-centered cubic metals, but quite different from the structures seen in fatigued aluminum crystals. It is suggested that the sub-structure is formed as the result of a stress concentration effect at the roots of intrusions, and that the differences between fatigue structures observed in aluminum and aluminum-magnesium crystals are explainable in terms of ease of cross-slip.

23,653 ON THE DETERMINATION OF THE NATURE OF DISLOCATION LOOPS by B. Edmondson and G.K. Williamson (Berkeley Nucl. Lab.); Phil. Mag., Vol. 9, pp. 277-283, Feb. 1964

A simplification of the electron microscope method for determination of the nature of dislocation loops is described. Full determination of the relevant diffraction conditions and of the Burgers vectors of the loops are avoided and knowledge of the sense of inclination of the loops and of the rotations of image and diffraction pattern is not required.

23,654 DISLOCATIONS IN FERROELECTRIC TRI-HYDROGEN LITHIUM SELENITE SINGLE CRYSTALS by H. Iwasaki (Radio Res. Labs., Tokyo); Japanese J. Appl. Phys., Vol. 3, p. 59, Jan. 1964

Etch pits have been observed on the crystal faces of ferroelectric tri-hydrogen lithium selenite crystals. Etching in ethyl alcohol reveals well-defined pits which have clear tips and are often pyramidal in shape. Density of pits is not uniform, varying from $10^4/cm^2$ to $10^6/cm^2$ on (110) and (10$\bar{1}$) faces. From the observations made, it is concluded that pits grow at the intersections of dislocation lines with the crystal face.

23,655 ENERGY OF DISLOCATIONS AND ETCH PITS IN SODIUM CHLORIDE CRYSTALS by E.M. Nadgornyi (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1991-1992(L), Mar. 1964

The dislocation energy for the formation of etch pits in NaCl crystals is estimated on the assumption that the normal rate of etching is proportional to the dislocation energy. The results show that during the analysis of the effect of the localized dislocation energy on etching processes, the deformation energy should be taken into account up to a distance of about 6b where b is the Burgers vector.

23,656 SUBSTRUCTURE AND DISTRIBUTION OF DISLOCATIONS IN SINGLE CRYSTAL AND POLYCRYSTALLINE ALUMINUM by B.M. Rovinskiy, Ye.P. Kastyukova and V.G. Lyutsau (Machine Bldg. Inst.); Investigation of Dislocation Structures, pp. 85-96, Nov. 29, 1963, Trans. from Kristallografiya, Vol. 8, pp. 657-662, July-Aug. 1963; STAR, Vol. 2, p. 504(A), Feb. 23, 1964 JPRS-22076; OTS-63-41255, $2.25

The high resolution methods of X-ray diffraction microphotography and microscopy were utilized for investigation of single crystal and polycrystalline specimens of pure aluminum (00.996%). It was shown that a combination of these methods uncovers the substructural components of different scales, the direction and magnitude of their disorientation, and the dislocation distribution.

23,657 DISLOCATIONS AND DISLOCATION LOOPS IN DEFORMED IRON by S.M. Ohr and D.N. Beshers (Columbia U.); Bull. Am. Phys. Soc., Vol. 9, p. 230(A), Mar. 1964

Crystallographic analyses of dislocations and dislocation loops in deformed bcc iron observed in the electron microscope have been carried out by applying the electron-diffraction theory of contrast at dislocations. Dislocations in deformed iron are in the form of tangles, with interspersed clusters of dislocation loops, from the very first stage of deformation. Crystallographic analyses show that the tangles consist of dislocations of two distinct Burgers vectors, in the ratio of approximately two to one. The dislocations of the primary system are com-

posed of segments of both signs, in roughly equal proportion. The Burgers vector of a majority of dislocation loops is identical to that of the primary dislocations, and the rest of the loops belong to the secondary system. The loops are found to be pure-edge prismatic dislocations lying in {111} planes, and are identified as being of vacancy type. From a consideration of the elastic theory of defect interaction, it is concluded that the interactions of dislocations with dislocations of dissimilar Bergers vectors and the formation of a cluster of small loops around the dislocations and junctions are responsible for formation of dislocation tangles.

23,658 DISLOCATIONS IN POLYMER CRYSTALS by E. Passaglia (Natl. Bur. Stand.) and H.D. Keith (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 256(A), Mar. 1964

The various dislocations likely to play a role in plastic deformation of crystals of n alkanes, extended-chain polymer crystals, and chain-folded polymer crystals have been examined on the assumption that primary bonds cannot be broken in backbone molecular chains. Reference was made specifically to the polyethylene structure. The assumption that primary bonds not be broken, together with the further restrictions brought about by chain-folding, limits substantially the number of dislocations and glide processes. It is shown that deformations of appreciable magnitude in chain-folded polymer crystals almost certainly cannot be attributed solely to dislocation mechanisms.

23,659 ARTIFICIAL SHEAR DEVELOPMENT AND DISLOCATION STRUCTURE IN SODIUM CHLORIDE CRYSTALS by E.M. Nadgornyy and A.V. Stepanov (Phys. Tech. Inst. A.F. Ioffe); Investigation on Dislocation Structures, pp. 60-84, Nov. 29, 1963, Trans. from Kristallografiya, Vol. 8, pp. 641-651, July-Aug. 1963; STAR, Vol. 2, p. 504(A), Feb. 23, 1964 JPTS-22076 OTS-63-41255, $2.25

The results of a study of sodium chloride crystals with different amounts of impurities, from the viewpoint of characteristics of selective etching, dislocation structure of artificial shear, and slip dislocations are given. The dependence was obtained for the rate of motion of edge and screw dislocations as a function of shear stress. The cited data explain the characteristic behavior of dislocations in these crystals.

23,660 DISLOCATION STRUCTURE IN THE CONCENTRATED LOADING REGION OF PbS CRYSTALS by A.A. Urusovskaya, R. Tyaagaradzhan and M. V. Klassen-Neklyudova (Acad. Sci. USSR); Investigation on Dislocation Structures, pp. 23-37, Nov. 29, 1963, Trans. from Kristallografiya, Vol. 8, pp. 625-631, July-Aug. 1963; STAR, Vol. 2, p. 503(A), Feb. 23, 1964 JPRS-22076; OTS-63-41255, $2.25

The dislocations in a rosette, formed by the pressure of a diamond indentor, were studied by a method of selective etching. Deformation was developed by slippage along (100) planes, as a result of which dislocation rosettes on the plane of a cube had only four rays and not eight, as was observed in NaCl crystals. In contrast to NaCl, dislocations in PbS were located to one side of the piercing point, strictly in the slippage planes. Dislocations of small loops originated, apparently, by multiple inclusions. Deformation in the direction of the load action was propagated over long distances by the formation of small loops.

23,661 CRYSTAL LATTICE STATE AND DISLOCATION DENSITY IN AUSTENITE AND FERRITE DURING PHASE TRANSFORMATIONS by L.I. Mirkin and Ya.S. Umanskiy; Dislocation Studies, pp. 1-7, Mar. 4, 1964, Trans. from Izv. Vysshikh Uchebn. Zavedenii, Fiz., No.3, pp. 212-217, 1960; STAR, Vol. 2, p. 1043(A), Apr. 23, 1964 JPRS-23509; OTS-64-21709, $1.00

The fine intragranular structure of brand 45 steel (0.4% C) and steel with 0.4% C and 12% Mn was investigated after quenching from the temperatures 920° to 1200°C and tempering at 200° to 700°C. The use of a method of determining the dislocation density according to the broadening of lines on X-ray photographs was proposed for investigating the processes of heat treatment. Data were obtained on the variation of the dislocation density of austenite and ferrite during the quenching and tempering of steel. A probable dislocation mechanism was proposed for the processes that occur in the α and γ phases during quenching and tempering.

23,662 REVEALING DISLOCATIONS ON CLEAVAGE PLANES OF CUPROUS OXIDE by A.I. Andrieveskii and G.I. Mocharnyuk (L'vov Polytechnic Inst.); Soviet Phys.-Cryst., Vol. 8, pp. 633-635(L), Mar.-Apr. 1964

A study of the dislocations in (111) cleavage planes of Cu_2O crystals is reported. It is found that the etch pits are arranged quite irregularly, and the dislocation density increases no less than an order of magnitude after the crystals are split. With increase in distance from the cleavage surface into the specimen, the dislocation density gradually decreases. An examination of the dislocations on the cleavage planes shows that the [111] direction is along the external surface of the plate, perpendicular to the cleavage plane.

23,663 NATURE OF DEFECTS IN HEAT-TREATED SILICON CONTAINING OXYGEN by J.R. Patel (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 288(A), Mar. 1964

Previous work has shown that silicon heated at 1000°C gives rise to strain centers presumably due to a clustering of oxygen. The present investigation explores further the nature of the defects due to this clustering phenomenon. Dislocation-free crystals of silicon have been diffused with oxygen at about 1300° to 1350°C. Examination of these crystals by transmission electron microscopy revealed no defects. When the diffused crystals were heat-treated at 1000°C, a variety of defects was observed by electron microscopy. Among the defects observed were dislocation loops, stacking faults, and unresolved defects giving rise to dislocation loops. When a crystal previously heated at 1000°C was subsequently heated at 1350°C, no defects were observed. A floating-zone crystal grown in an oxygen atmosphere was examined after heat treatment at 1000°C; a high concentration of defects were observed lying along dislocation lines originally present in the crystal.

23,664 X-RAY-INDUCED DISLOCATION GENERATION IN SODIUM CHLORIDE by R.L. Wolfe and C.L. Bauer (Carnegie Inst. Tech.); J. Appl. Phys., Vol. 35, pp. 658-663, Mar. 1964

The strain distribution, induced by subjecting one-half of a sodium chloride single crystal to X-rays while shielding the other half, has been investigated with a dislocation etch pit technique. Due to the expansion of the irradiated half, a strain gradient arises antisymmetrically about the plane of the interface that is sufficient in magnitude to cause plastic deformation in the protected half, but not in the irradiated half of the crystal. The plastic deformation takes the form of a number of high-density dislocation bands which tend to align in a [100] direction. The bands increase in number but not appreciably in size as irradiation proceeds. The absence of plastic deformation in the irradiated half can be explained by the fact that irradiation raises the yield strength to such a level that the strain is not sufficient to induce plastic flow. In the protected region, however, dislocations are generated and glide until they impinge, causing discrete bands to form roughly parallel to (100) planes. From an analysis of the data, an estimate of the magnitude of the strain produced at the interface and the relationship between the strain and the number of F centers generated can be obtained. The results, although in some ways unexpected, are consistent with previous experiments performed on X-irradiated alkali halides.

23,665 DIFFUSION-INDUCED DISLOCATION NETWORKS IN Si by R.J. Jaccodine (Bell Labs.); Appl. Phys. Lett., Vol. 4, pp. 114-115(L), Mar. 15, 1964

A transmission electron microscopy investigation of the dislocations induced in silicon by the diffusion of shallow layers of large dopant concentration is reported. In phosphorus-diffused samples the dislocations were generally of the a/2 <110> type. Straight dislocations were generally aligned along the <110> or <112> directions, and the densities were about 10^8 discloations/cm^2. The density and spacing of the observed dislocation lines suggest that the fine striations observed by others are not the actual dislocation network joining the two regions of different lattice parameter produced by the diffusion, but are due to slip lines resulting from large groups of gliding dislocations on slip planes.

23,666 DISLOCATION BOUNDARIES IN IRRADIATED SODIUM NITRATE SINGLE CRYSTALS by R.D. Martini and J. Byrne (Stevens Inst. Tech.); J. Phys. Chem. Solids, Vol. 25, p. 147(L), Jan. 1964

A study of dislocation behavior in irradiated $NaNO_3$ crystals is reported. By examining freshly cleaved surfaces in the as grown and irradiated condition, it is found that cleavage step patterns typical of dislocation boundaries are present on irradiated crystal surfaces. In the case of non-irradiated crystals, the distribution of cleavage steps are found to be random. Dislocation boundaries connected with cleavage steps are of the tilt-twist boundary type with both edge and screw dislocations constituting such boundaries. The diffusion assisted dislocation climb mechanism is offered as a tentative explanation for the occurrence of this type of boundaries in irradiated crystal surfaces.

23,667 CHARGED DISLOCATIONS IN SILVER CHLORIDE by W. McGowan and L. Slifkin (U. North Carolina); Bull. Am. Phys. Soc., Vol. 9, p. 263(A), Mar. 1964

The sign of the electrical charge on dislocations in silver chloride crystals has been investigated, using an indentation technique (50-gm load dropped 1 mm) to produce a strong, inhomogeneous stress field. The indenter itself was used as the probe electrode with the signal passing through a unity-gain amplifier (input resistance 10^{12} Ω, input capacitance 0.1 pF) and photographed on an oscilloscope screen. In the temperature range 5°-80°C the indenter was positive relative to the bottom of the crystal for all pulses. Pulse heights were of the order of several volts at room temperature, decreasing in magnitude with increasing temperature. The rise time was approximately equal to the time during which deformation takes place. The inhomogeneous stress field generates dislocations near the surface and forces them into the interior. The positive signal on the indenter thus indicates that these moving dislocations carry negative charge.

23,668 PEIERLS FORCE DEPENDENCE ON DISLOCATION WIDTH by R.H. Hobart (Batelle Inst.); Bull. Am. Phys. Soc., Vol. 9, p. 229(A), Mar. 1964

There is a controversy as to how rapidly the Peierls force vanishes with increasing dislocation width in the Frenkel-Kontorova dislocation model: V.L. Indenbom argues that it falls off exponentially and mentions an unpublished argument by I.M. Lifshitz that it falls off as the inverse fifth power. In this calculation, the most nearly central atom of the Frenkel-Kontorova dislocation is held fixed and the positions of its two neighbors are adjusted for a single dislocation configuration. If the configuration lacks symmetry, an external force on the central atom alone is generally necessary to hold the configuration static. The integral of this Peierls force over the displacement of the central atom between neighboring stable and unstable dislocation equilibria is the Peierls energy barrier. The maximum of the Peierls force for widths λ, in units of the atom spacing b, of 2, 4, 6, 8, 10 is 1.7, 3.6×10^{-2}, 2.5×10^{-4}, 1.2×10^{-6}, 4.0×10^{-9}, respectively, in units of A/b, where A is the amplitude of the sinusoidal potential-energy substrate. This is nearly an exponential falloff. On a semilog plot, the slope is slowly decreasing with increasing width so that the slope -2.8 at 10 supports Indenbom's prediction, for which the slope is $-\pi$.

23,669 DEFECTS IN SOLIDS AT HIGH VELOCITY DEFORMATION by A.N. Stroh (MIT); Proc. of Symp. on Struct. Dyn. under High Impulse Loading, May 1963, pp. 59-78; STAR, Vol. 2, p. 621(A), Mar. 8, 1964 ASD-TDR-63-140; AD 408 777

The behavior of dislocations moving at both subsonic and supersonic velocities is reviewed. At supersonic velocities energy is radiated and a rather high stress is needed to maintain the motion. The properties of edge and screw dislocations which differ much more at high velocities than at low are contrasted. A major problem of dislocation dynamics is the nature of the resistive forces limiting the velocity, and current ideas on this are discussed. The dependence of the dislocation velocity on the applied stress has been measured for several materials, but the relationship is not yet fully understood. The production of point defects by rapidly moving dislocations is considered.

23,670 DISLOCATION MOBILITY BELOW 1°K IN fcc METALS by G.A. Alers and J.E. Zimmerman (Ford Motor); Bull. Am. Phys. Soc., Vol. 9, p. 230(A), Mar. 1964

In pure fcc metals, dislocations move in the stress field of high-frequency sound waves and lower the measured elastic modulus. This lowered modulus shows a temperature dependence at very low temperatures, which indicates that the dislocation motion becomes restricted as the temperature approaches 0°K. The elastic moduli were measured by using an ultrasonic technique capable of detecting modulus changes of the order of a part in 10^7. Adiabatic-demagnetization techniques were used to attain temperatures of 0.12°K. The results on a high-purity copper crystal in which dislocations had lowered the modulus by 0.6 per cent at 77°K showed that the modulus varied as $T^{\frac{1}{4}}$ and changed by 0.3 per cent in going from 10° to 0.12°K. No changes in attenuation were observed in this temperature range, thereby ruling out the possibility that the modulus changes were associated with a simple thermally activated relaxation process. Irradiation with γ-rays to pin the dislocations decreased the size of the temperature dependence while retaining the $T^{\frac{1}{4}}$ law. Less-pure crystals showed a T^1 law in this same temperature range and a Cu crystal with 0.13 wt. per cent Au showed no temperature dependence below 10°K.

23,671 DISLOCATION JUMPS IN LiF SINGLE CRYSTALS by V.B. Pariiskii, A.I. Landau, and V.I. Startsev (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1002-1007, Nov. 1963

The dislocation jumps in LiF single crystals etched in the absence of any external loading have been investigated. The experiment supports the hypothesis that dislocation jumps are due to the presence of local blocking points which prevent the motion of the dislocations and are removed by etching.

23,672 SPONTANEOUS DISLOCATION JUMPS IN LITHIUM FLUORIDE SINGLE CRYSTALS by V.B. Pariiskii, A.I. Landau and V.M. Borzhkovskaya (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1876-1879, Mar. 1964

An investigation of the effect of the spontaneous abrupt movement of dislocations in LiF single crystals is reported. By statistical treatment of the experimental data it is shown that this motion in fact has an abrupt character and is connected with the overcoming of local barriers by a moving dislocation. An experimental relationis obtained between the mean length of the spontaneous displacement of the dislocations and the relaxation time in the single crystal. On the basis of the experimental data, the mean stopping time of the dislocations between successive jumps is evaluated.

23,673 SPONTANEOUS SHIFTING OF DISLOCATIONS IN SINGLE CRYSTALS OF LiF by V.B. Pariyskiy, A.I. Landau and V.M. Borzhkovskaya; Soviet Studies on Dislocation Structures, pp. 15-24, Jan. 30, 1964, Trans. from Fiz. Tverd. Tela, Vol. 5, pp. 2570-2575, Sept. 1963; STAR, Vol. 2, p. 915(A), Apr. 8, 1964 JPRS-22981; OTS-64-21430, $1.25

The phenomenon of a spontaneous step-like motion of dislocations in single crystals of LiF, which are not subjected to any external influence at the time of such motion has been investigated. It is shown that, on the basis of statistical processing of experimental data, the motion is actually of a step-like nature and is connected with moving dislocations overcoming local stops. The experimental dependence of the average length of a spontaneous shift in a dislocation on the relaxation time of a single crystal was obtained. It is also shown that the spontaneous step-like motion of the dislocations in single crystals of LiF is caused by the same stops that cause the step-like motion of dislocations when the surface of a crystal is etched. The average time a dislocation remained between two successive shifts (15 to 30 minutes) was estimated on the basis of the experimental data that were obtained.

23,674 THE STRESS DEPENDENCE OF DISLOCATION VELOCITY AND ITS RELATION TO THE STRAIN RATE SENSITIVITY by J. Christian (Case Inst. Tech.); Acta Met., Vol. 12, pp. 99-102(L), Jan. 1964

An analysis of the intrinsic relation between dislocation velocity and the stress developed in dynamic theories of yielding is presented. The relation is usually expressed as $\nu = (\tau/\tau_0)^m$ where ν = velocity, τ = resolved shear stress, and τ_0 and m are characteristic of the material. The validity of the above relationship is established by the flow stress data. In some materials "m" was found to be sensitive to impurity content and history.

23,675 ON THE ELASTIC FIELD AROUND AN EDGE DISLOCATION WITH APPLICATION TO DISLOCATION VIBRATION by J. Kiusalaas and T. Mura (Northwestern U.); Phil. Mag., Vol. 9, pp. 1-7, Jan. 1964

The elastic field around a long, straight edge dislocation moving with an arbitrary velocity is derived in the form of time integrals. An electromagnetic analogy, which is known to apply to a screw dislocation, is found to be absent. The results are applied to an edge dislocation oscillating with a small amplitude. A brief discussion of the scattering properties shows no significant difference between screw and edge dislocations.

23,676 THE ELASTIC ENERGY OF A RHOMBUS-SHAPED DISLOCATION LOOP by R. Bullough and A.J.E. Foreman (AE Res. Estab., Harwell); Phil. Mag., Vol. 9, pp. 315-329, Feb. 1964

The elastic strain energy of a rhombus-shaped dislocation loop is calculated for an arbitrary rotation about the minor or major diagonal axis. For loops less than about one micron in size and constrained to move on the glide prism, a shallow minimum in the energy exists displaced from the pure edge loop orientation. The depth of the minimum and its displacement from the pure edge orientation increase as the loop size decreases. The results provide an explanation for the observation by Makin and Hudson (1963) of such loops lying in {012} planes rather than in the {011} plane normal to the Burgers vector. The importance of the work done by the dislocation core tractions is emphasized and in particular its dependence on the method adopted for formally generating the dislocation loop. The misorientation effect is enhanced if the loop becomes extended into a pair of partials with a ribbon of stacking fault. An estimate of the core energy on the basis of an extended Peierls model does not preclude the effect.

23,677 ELASTIC PROPERTIES OF A COMPOUND TILT DISLOCATION WALL by N. Mikuriya (Meijo U., Nagoya); J. Phys. Soc. Japan, Vol. 19, pp. 258-264, Mar. 1964

The properties of dislocation wall consisting of an infinite number of two kinds of edge dislocations whose Bergers vectors are at right angles to each other, are investigated on the basis of isotropic elasticity theory. The stress field in the region apart from the wall is divided by the planes perpendicular to the wall into unequally spaced bands, which are composed of positive and negative regions of the stress field. On the other hand, the dilatational strain field is divided into equally spaced bands. It is concluded that the pinned compound tilt dislocation wall is a more effective barrier than the simple tilt wall for the penetration of dislocations.

23,678 SOME ELASTIC PROPERTIES OF DISLOCATION DIPOLES by J.C.M. Li and P.R. Swann (U.S. Steel); Bull. Am. Phys. Soc., Vol. 9, p. 229(A), Mar. 1964

The equilibrium of dislocation dipoles under stress is studied. It is found that without external stress there exist no equilibrium positions for two dipoles of edge-, screw, or mixed-type freely slipping in two parallel slip planes. To maintain equilibrium, an external stress is required such that the two exterior dislocations are pulled apart to overcome their attraction and that the two interior dislocations are, in general, pushed together to overcome their repulsion. Dislocations of opposite signs emitted from two Frank-Read sources can meet and pass each other without the help of external stress. The result is the formation of many dipoles. The termination of these dipoles by cross slipping and the reorientation of the terminated dipoles to the edge orientation were discussed. The relation of all these phenomena to the formation of tangles and work-hardening was pointed out.

23,679 DILATATION FIELD OF SCREW DISLOCATIONS by Y.T. Chou (U.S. Steel); Bull. Am. Phys. Soc., Vol. 9, p. 229(A), Mar. 1964

The existence of a dilatation field owing to screw dislocations was discussed. It was found that the screw segments in bcc systems do possess dilatation fields; on the other hand, the screw segments in fcc and hcp systems do not. It is likely that such a difference between bcc and fcc systems may be responsible for certain different characteristics in plastic deformation of the two systems, such as the yielding phenomenon and work-hardening. A representative example was shown. The screw-dilatation field consists of 6 sectors of alternate expansion and contraction. The dilatation fields of screw arrays were also discussed.

23,680 DIRECT OBSERVATIONS OF INTERACTIONS BETWEEN IMPERFECT LOOPS AND MOVING DISLOCATIONS IN ALUMINIUM by J.L. Strudel and J. Washburn (U. California, Berkeley); Phil. Mag., Vol. 9, pp. 491-506, Mar. 1964

Observations have been made by transmission electron microscopy on the interactions between faulted dislocation loops and moving dislocations in high purity aluminum. Thin single crystals were quenched from 650°C and 540°C into water at 0°C. In both cases most of the loops enclosed a stacking fault. Their average diameter was 250 A in the first case, 900 A in the second case. Surface orientation for all foils was (110), which made possible easy identification of Bergers vectors for both loops and moving dislocations. When a moving dislocation came close to or in contact with a loop, the stacking fault was always completely destroyed and part or all of the loop was brought to the surface of the foil by prismatic glide.

23,681 INTERACTION BETWEEN VACANT LATTICE SITES AND DISLOCATIONS by D. Kuhlmann-Wilsdorf (U. Virginia) and L.A. Girifalco (U. Pennsylvania); Bull. Am. Phys. Soc., Vol. 9, p. 397(A), Apr. 1964

The interaction energy between vacancies and internally stressed regions in monatomic monovalent metals consists of 4 contributions: (1) volume-pressure work done by the normal stresses on the volume of relaxation, binding vacancies to compressed regions; (2) reduction of stored energy because the surroundings of a vacancy are elastically soft, attracting vacancies into every stress gradient; (3) changed electronic energy of a vacancy in stress fields. Since the electronic energy is proportional to the width of the occupied portion of the conduction band, this causes vacancies to migrate to dilated regions; and (4) dependence of vibrational entropy, due to localized modes on normal strains. The effect of the last term can be regarded as a binding energy attracting vacancies into dilated regions with a magnitude proportional to the absolute temperature. The combined effect of the said contributions is to bind vacancies to all types of dislocations, with up to 0.06 ev at T = 0°K, rising up to 0.6 ev in the most dilated parts in the centers of cores at the melting point. However, vacancies are repelled from the compressed regions in the core of edge and near-edge dislocations, so that these cannot climb easily.

23,682 DISLOCATION INTERSTITIAL INTERACTIONS IN SINGLE-CRYSTAL W AND Ta by G.S. Baker and S.H. Carpenter (Aerojet Genl.); Bull. Am. Phys. Soc., Vol. 9, p. 230(A), Mar. 1964

Dislocation interstitial interactions have been investigated in zone-refined single-crystal tungsten and tantalum by means of internal-friction measurements. A Marx piezoelectric composite oscillator resonating at 50 kc/sec was used to measure log decrement vs strain amplitude and temperature. Results show that the amplitude-independent damping of slightly cold-worked single-crystal tungsten anneals out with time at temperatures above ~400°C. The annealing has been explained in terms of the diffusion of interstitial impurities, according to the $t^{2/3}$ law of Bilby and Cottrell, to the dislocations pinning them and rendering them immobile. An activation energy for the annealing has been found to be ~48 kcal/mole. The interstitial has not been identified. Amplitude independent damping of single-crystal tantalum measured immediately following deformation has been found to anneal out with time at room temperature. Annealing times for tantalum have been found to be too short to allow for the long-range diffusion of interstitials required for Cottrell-type pinning. The annealing mechanism in tantalum is believed to be the reorientation of interstitials in the dislocation strain field as proposed by Snoek.

23,683 INTERACTION OF DISLOCATIONS DURING CRYSTAL TWINNING by V.I. Startsev, V.Z. Bengus, S.N. Komnik and F.F. Lavrent'yev (Acad. Sci. UkrSSR); Invest. on Dislocation Structures, pp. 38-59, Nov. 29, 1963, Trans. from Kristalografiya, Vol. 8, pp. 632-640, July-Aug. 1963; STAR, Vol. 2, p. 504(A), Feb. 23, 1964 JPRS-22076; OTS-63-41255, $2.25

Experimental investigations of certain effects, during twinning of crystals of calcite and zinc, that result from the interaction of twinning dislocations among themselves and with other dislocations are reported. Theoretical treatments of these phenomena are presented.

23,684 DISLOCATION DISTRIBUTIONS IN DEFORMED COPPER SINGLE CRYSTALS by Z.S. Basinski (Natl. Res. Council, Ottawa) and S.J. Basinski (Dept. of Mines and Tech. Surveys, Ottawa); Phil. Mag., Vol. 9, pp. 51-80, Jan. 1964

Dislocation etch pit distributions and slip lines have been studied on copper single crystals oriented for single glide and deformed in tension at 4.2°K. Sl lines on the cross slip plane were observed from the earliest stages of deform tion and their character changed during the transition to stage II. The distrib tion of forest dislocations is much more isotropic and less homogeneous than t of dislocations crossing other planes. The ratio of the forest to other dislocations densities in stage I is about 1:15 but tends to 1 in stage II. The flow st correlates better with the forest than with main glide dislocation density. T experiments support this conclusion.

23,685 DISLOCATION CHARACTERISTICS AND WORK-HARDENING PHE NOMENA DURING THE PLASTIC DEFORMATION IN MONOCRYSTALLIN GERMANIUM by A. Bacchilega and P. Gondi (U. Bologna); Nuovo Cimento Vol. 31, pp. 929-949, Mar. 1964

Deformation tests by torsion have been carried out on germanium slices, with special reference to the various work-hardening stages and to their dependen on temperature and strain rate. Corresponding to each stage the dislocation c tributions have been observed by means of transmission electron microscopy. the easy glide region there appear single rows of parallel and almost equally spaced dislocations; stage II is characterized by strong increases of the dislo cation density, by the appearance of nodes and the absence of pile-ups; stag III by a constant or decreasing dislocation density and the development of boundaries. The nature of dislocations has been analyzed by means of diffrac tion contrast. The results have been interpreted in terms of thermal and athe mal hardening, with special reference to the absence of pile-ups.

23,686 STUDY OF THE ANISOTROPY OF MECHANICAL PROPERTIES OF NaCl SINGLE CRYSTALS FROM OBSERVATIONS OF THE DISLOCATION DISTRIBUTION ON THE (111) FACE by Yu.S. Boyarskaya and M.I. Val'kov skaya (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1690-1694, Feb. 1964

It is shown that dislocation etch pits appear on the (111) face of NaCl if the surface is properly polished and then etched with acetic acid. A study is mad of the dislocation distribution on this face. Dislocation zones around scratch along $[\bar{1}\bar{1}2]$ and $[11\bar{2}]$ differ in width, external form and distribution. The dis location distributions are also different near the ends of scratches. All these factors indicate polarity of mechanical properties along these directions.

Dislocation Relaxation in Nb and Ta - See 24,555 and 24,556

Dislocations in:
Ge - See 24,522
$BaTiO_3$ - See 23,806
$ZnWO_3$ - See 23,802

STACKING FAULTS, TWINS, etc.

23,687 STACKING FAULTS IN FACE-CENTERED CUBIC METALS AND ALLOYS by R.E. Smallman and K.H. Westmacoh (A.E. Res. Estab., Harwell); Phil. Mag., Vol. 2, pp. 669-683, 1957

Stacking faults on the (111) planes of several fcc metals and alloys have bee introduced by cold work, and estimates of the stacking fault probability, a, have been obtained from changes produced in the Debye-Scherrer spectrum. The faulting probability increases on alloying from one plane in 300 in Cu, t one plane in 25 for some high solute content alloys containing Zn, Al, Sn on Ge. Both neutron irradiation (5×10^{19} nvt) and "quenched-in" vacancies hav little significant effect on the faulting parameter. Lowering the temperature deformation increases the faulting probability, but in Cu the faults 'anneal-out' at room temperature after several hours. Line broadening analysis shows that the dislocation density is increased on alloying and also by lowering the deformation temperature. It is suggested that the faulting way be accounted by the regions between separated half dislocations. Ribbons of stacking faults as given by extended dislocations and "infinite" stacking faults produced on splitting of dislocations at high stresses are considered and estimates of fault energy are made. Some work on segregation of solute atoms to faults is repor ed with particular reference to the alloys Ag-Au and Cu-Al.

23,688 THE OCCURRENCE OF STACKING FAULTS IN METALLIC SYSTEMS by J. Spreadborough (U. Museum, Oxford); Phil. Mag., Vol. 3, pp. 1167-1173, 1958

A possible qualitative interpretation of the occurrence of stacking faults in metals and alloys is outlined, using an extension of the ideas of Altmann, Coulson and Hume-Rothery. The metals Ca, Sc and Ti, the ε-phase in Fe-Mn and the α-solid solutions of various B sub-group elements in the noble metals are treated as examples. The effect of temperature on hybrids is briefly discussed.

23,689 THE DEPENDENCE OF ROLLING TEXTURE ON STACKING FAULT ENERGY by R.E. Smallman and D. Green (U. Birmingham, England); Acta Met., Vol. 12, pp. 145-154, Feb. 1964

The transition from the texture near the ideal orientation, {153} <112> characteristic of pure Cu heavily rolled at room temperature to that characteristic of brass, {110} <112>, has been examined in a series of alloy systems of known stacking fault energy. It is shown that the fundamental factor governing the change in rolling texture is the decrease in stacking fault energy on alloying and that the {110}<112> texture is not confined specifically to alloys, but is a feature of any material with γ less than about 35 ergs/cm^2, rolled at a temperature not higher than 0.25 T_m; the critical stacking fault energy depends on the rolling temperature. Quenching and irradiation has no appreciable effect on the rolling texture of spec-pure metals, and it is concluded that the transition is associated with the difficulty of cross-slip. The possibility of estimating the stacking fault energy from rolling texture is discussed.

23,690 A DETERMINATION OF THE STACKING-FAULT ENERGY OF SOME PURE fcc METALS by I.L. Dillamore, R.E. Smallman and W.T. Roberts (U. Birmingham, England); Phil. Mag., Vol. 9, pp. 517-526, Mar. 1964

A method for determining the stacking-fault energy of fcc materials has been developed using an already-established dependence of preferred orientation on stacking-fault energy. An empirically determined parameter, characteristic of the type of rolling texture exhibited by the metal, is related to the stacking-fault energy value obtained by measurements of dislocation node radius, and from the γ value for the three metals, Ag, Cu and Ni the stacking-fault energy of Th, Au, Pd, Rh, Pt and Yb has been obtained by interpolation using measured values of the texture parameter.

23,691 X-RAY DIFFRACTION STUDY OF DEFORMATION BY FILING IN bcc REFRACTORY METALS by E.N. Aqua and C.N.J. Wagner (Yale U.); Phil. Mag., Vol. 9, pp. 565-589, Apr. 1964

The bcc refractory metals, Nb, Ta, V, Cr and W, were cold worked by filing. The broadening of the powder pattern peaks was studied by Fourier analysis of the line shapes. The effective particle sizes, D_e(hkl), and root mean squared (rms) strains were measured in different crystallographic directions. Anisotropic values of particle sizes observed in Ta and Nb were an indication of faulting in these metals. The degree of anisotropy of particle sizes was much smaller in V; W and Cr showed isotropic particle sizes. The ratio of rms strains may be calculated from the directional variation of Young's modulus. The absolute magnitude of rms strains was also computed for isotropic bcc metals without faulting. The amount of faulting is observed to increase with the degree of elastic anisotropy of the bcc metals of the group Vb. Metals of group VIb show no X-ray diffraction evidence of faulting.

23,692 FAULTING IN EVAPORATED COPPER FILMS by R.W. Vook (Franklin Inst. Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 214(A), Mar. 1964

X-ray diffraction line profiles were obtained without removing the film from the vacuum system. The intrinsic stacking-fault probability α in the as-deposited films was determined from 111-200 relative peak shifts. The average value of α determined from several films was $\alpha = 0.013$. The twin-fault probability β was determined from the asymmetry of the 111 and 200 diffraction lines. If β_{hkl} is the twin-fault probability in the [hkl] oriented grains, then, for several films, the following average values were obtained: $\beta_{111} = 0.06$ and $\beta_{200} = 0.3$. All the broadening in the 111 and 200 diffraction lines obtained from the as-deposited films could be explained by the presence of twins and intrinsic stacking faults alone. This result suggests that the particle size in copper films deposited on glass at liquid-nitrogen temperature is quite large.

23,693 STACKING FAULT DENSITIES IN FILINGS OF SOME COPPER- AND SILVER-BASE SOLID SOLUTIONS by R.G. Davies and R.W. Cahn (U. Birmingham, England); Acta Met., Vol. 10, p. 621, 1962

Values of the stacking fault parameter α have been determined by means of Paterson's X-ray method for filings of primary solid solutions of Cu and Ag with various solutes. The change with composition of α, which is closely related to the stacking fault energy, is primarily determined by the electron,atom ratio; for a fixed electron/atom ratio, however, α increases as the valency of the solute increases. The variation of α with electron/atom ratio is nearly the same for two alloys containing solutes of the same valency which are of the same period as the solvent. For Ag alloys with divalent solutes, α increases with the separation of the periods of solvent and solute. The implications of these conclusions are discussed.

23,694 STACKING FAULTS IN COPPER-NICKEL ALLOYS by K. Nakajima (Tohoku U.); J. Phys. Soc. Japan, Vol. 14, pp. 1825-1826, 1959

An X-ray study of stacking fault energy (γ) in Cu-Ni alloys has revealed that γ increased rapidly as Ni content increased above 50 per cent.

23,695 STACKING FAULTS IN NICKEL SOLID SOLUTIONS by N.I. Noskova and V.A. Pavlov; Fiz. Metal. i Metallored., Vol. 14, pp. 899-903, 1962

The occurrence and energy changes of stacking faults in Cu-Ni and Co-Ni solid solutions have been studied by measurements of resistivity. The energy of stacking faults resulting from plastic deformation is found to decrease with increasing Cu or Co content in the Ni lattice. Stacking faults account for the 6% increase in resistivity of 40% Cu-Ni and 8% increase of 40% Co-Ni.

23,696 STACKING FAULTS AND DISLOCATIONS IN COPPER-ALUMINIUM AND COBALT-NICKEL ALLOYS by J.W. Christian and J. Spreadborough (U. Museum, Oxford); Proc. Phys. Soc. London, Vol. B 70, pp. 1151-1161, 1957

Stacking fault densities α' in heavily cold-worked powders of Cu-Al and Co-Ni alloys have been measured from the peak shifts, using Paterson's theory. The Fourier coefficients of the broadening function due to faults are calculated for the {111} and {200} powder lines, assuming equal densities of faults on all {111} planes; this enables the strain broadening function to be evaluated from the measured coefficients. This function has approximately a Cauchy shape. Dislocation densities estimated from the strain breadth ξ and mean square strain $\langle S^2 \rangle$ vary much less with composition than does α'. Faults and dislocations disappear on annealing, so there is a linear relation between ρ and α'. It is suggested that the stacking fault diffraction effects cannot be attributed to the fault ribbons in extended dislocations, as previously stated.

23,697 SEGREGATION OF SOLUTE ATOMS TO DEFORMATION STACKING FAULTS IN FACE-CENTERED CUBIC SOLID SOLUTIONS by K. Nakamima (Tohoku U.); Trans. Jap. Inst. Metals, Vol. 2, pp. 21-25, 1961

X-ray studies of the segregation of solute atoms to stacking faults in Cu-Al and Cu-Ni alloys are reported. Asymmetrical line broadening was observed in Cu-Al but not in Cu-Ni. For Cu-18.3% Al the center of gravity of the (111) diffraction line shifted 0.05° and was due to segregation of solute atoms and the deformation of stacking faults. The equation of Willis was used in investigating the effect of segregation on the diffraction pattern.

23,698 STACKING FAULTS OF COPPER-GERMANIUM ALLOYS by S. Koda, K. Nomaki and M. Nemoto (Tohoku U.); J. Phys. Soc. Japan, Vol. 18, Suppl. II, pp. 118-122, 1963

The determination of stacking fault energies in Cu-Ge alloys employing techniques based on X-ray diffraction, electron microscopy and the Suzuki effect is described. Data discrepancies are observed in measurements from the three techniques. The stacking fault energy of Cu-9 to 13% Ge is 0.88 erg/cm^2 (X-ray) and 10 erg/cm^2 (electron microscope).

23,699 X-RAY TOPOGRAPHIC STUDY ON STACKING FAULTS IN SILICON SINGLE CRYSTALS by M. Yoshimatsu (Rigaku Denki Ltd.); Japanese J. Appl. Phys., Vol. 3, pp. 94-103, Feb. 1964

Various types of stacking faults have been studied. Boundaries of stacking faults are concluded to be partial dislocations of the Shockley type. Stacking faults introduced by splitting of total dislocations into partial dislocations are also observed. By comparative studies of X-ray images with optical ones of the etched surface, it is found that some stacking faults consist of multi-planes of different dimensions.

23,700 CRYSTALLOGRAPHIC CONFIGURATIONS OF STACKING FAULTS AND PARTIAL DISLOCATIONS AND THEIR NUCLEATION IN EPITAXIALLY GROWN SILICON by S. Mendelson (Sprague Electric); Bull. Am. Phys. Soc., Vol. 9, p. 296(A), Mar. 1964

Stacking faults in epitaxially grown silicon are nucleated on the substrate surface and appear in the form of polyhedra bounded by stair-rod dislocations. On {111} substrates, they take the form of inverted truncated tetrahedra. It is shown that, if the fault nucleus is intrinsic, the propagating obtuse faults will be extrinsic if a stair-rod dislocation (a/6) <110> exists at their intersection, and intrinsic if a (a/3) <001> dislocation forms there. Both are stable, although the former is more stable and would be the case if the fault nuclei were formed by the "collapsed vacancy-disk mechanism." Calculations show that, if vacancy disks do form, they must do so by some mechanism other than by vacancy diffusion. Also, all the observed crystallographic configurations cannot be explained by this mechanism but can by the "faulted deposited 2-dimensional-layer" model and by the presence of a foreign substance (probably an oxide) on the substrate surface.

23,701 EFFECT OF GROWTH RATE ON STACKING-FAULT DENSITY IN EPITAXIAL SILICON LAYERS by M.R. Notis (Western Electric) and G.P. Conard (Lehigh U.); J. Appl. Phys., Vol. 35, pp. 695-697, Mar. 1964

The growth rate of an epitaxial silicon deposit affects the stacking-fault density of the deposited layer in a linear manner over the deposition range of 0.1 to 1.0 μ/min. The stacking-fault density is also inversely related to the substrate dislocation density for dislocation densities up to 5×10^3 cm^{-2}. The conditions for the formation of stacking faults, as described by various authors to

date, seem sufficient but not necessary for fault formation. The present work supports a vacancy condensation mechanism by which the low stacking-fault energy of the material creates a natural condensation of vacancies into stacking faults.

23,702 FORMATION OF STACKING FAULTS IN POLYCRYSTALLINE SILICON BRONZE UNDER TENSILE DEFORMATION by H.M. Otte and D.O. Welch (Res. Inst. Adv. Studies); Phil. Mag., Vol. 9, pp. 299-313, Feb. 1964

The changes in the X-ray Debye-Scherrer diffraction pattern, as a function of plastic strain, have been measured for a silicon bronze (Cu-6.6 at.% Si-1.2 at.% Mn) tensile specimen. Analysis of line positions and line breadths gave the following results. The stacking-fault probability increased with extension, and near fracture (70-75% extension and about 70 kg/mm^2 stress) its value was around 0.008. The extrapolated, or 'true' lattice parameter, measured in the radial direction, decreased, but not smoothly. The longitudinal stress calculated, using known elastic constants and theory, from the changes in lattice parameters accompanying the plastic deformation, compared favorably with that of the stress-strain curve from a standard mechanical test. Evaluation of all the results obtained for the Cu-Si-Mn alloy suggest that it has a stacking-fault of 2-6 erg/cm^2, which places it in the intermediate range of values observed for other similar alloys. Examination by X-ray diffraction of the alloy in the filled or drawn condition showed a much higher stacking-fault density, although analysis of the data still yielded the same stacking-fault energy. The influence of the mode of deformation on the extent of faulting is thus clearly demonstrated.

23,703 DETERMINATION OF THE PREDOMINANT TYPE OF STACKING FAULT IN COBALT BY NUCLEAR MAGNETIC RESONANCE AND ELECTRON MICROSCOPY by L.E. Toth, T.R. Cass, S.F. Ravitz and J. Washburn (U. California, Berkeley); Phil. Mag., Vol. 9, pp. 607-616, Apr. 1964

Consideration of the effect on the nuclear magnetic resonance spectrum of the differences in interplanar spacing of the various close-packed layers in cobalt stacking faults had previously indicated the stacking faults to be predominantly intrinsic. This identification has been confirmed in the present investigation by two independent methods, (1) the effect of cold-working on the NMR spectrum, and (2) application of the theory of stacking-fault fringe contrast to electron micrographs.

23,704 DIRECT OBSERVATION OF DISAPPEARANCE AND COLLAPSE OF STACKING-FAULT TETRAHEDRA IN GOLD FOILS DURING ION BOMBARDMENT IN THE ELECTRON MICROSCOPE by L.M. Howe and J.F. McGurn (Atomic Energy of Canada); Appl. Phys. Lett., Vol. 4, pp. 99-102(L), Mar. 15, 1964

The role of interstitials in the disappearance and collapse of stacking-fault tetrahedra in gold foils is discussed. Room-temperature bombardment with 100 kev O-ions of 99.999% pure Au foils containing stacking fault tetrahedra resulted in the appearance of visible defects and the disappearance of the tetrahedra. Similar results were observed when the foils were bombarded with 100 kev O-ions below 30°K. After the tetrahedra were completely removed, the ion bombardment was stopped and the temperature of the foil raised to 285°K. No change in radiation-produced defects was observed as the temperature was increased. A foil which was bombarded below 30°K to the point where radiation damage was visible and some tetrahedra were still present was heated to room temperature without additional ion bombardment. No tetrahedra were observed to disappear. These results indicate that the tetrahedra collapse in the absence of migrating interstitials and that the radiation-produced defects are vacancy clusters.

23,705 STACKING FAULTS, RIBBONS AND THE FORMATION OF EXTENDED JOGS IN TIN-DISULPHIDE by R. Siems, P. Delavignette and S. Amelinckx (S.C.K.-C.E.N.,MOL (Belgium); Phil. Mag., Vol. 9, pp. 121-152, Jan. 1964

Dislocations in tin-disulphide occur as widely dissociated ribbons, proving that the stacking-fault energy is very small. The geometry of possible stacking faults is discussed and the energy of the different faults is compared. It is shown that the proximity of the surface visibly influences the ribbon widths. From the presence of threefold ribbons it is concluded that two different glide planes are operative in this substance; in one of them glide takes place by a synchro-shear movement. A detailed study is made of possible intersections of ribbons resulting in the formation of extended jogs. On movement, such jogs produce trails.

23,706 GRAIN BOUNDARY MOBILITY AND ITS EFFECTS IN MATERIALS CONTAINING INERT GASES by M.V. Speight and G.W. Greenwood (Berkeley Nucl. Labs.); Phil. Mag., Vol. 9, pp. 683-689, Apr. 1964

The conditions under which grain boundaries can be pinned by solid precipitates are established but precipitates in the form of inert gas bubbles are known to move by surface diffusion of the matrix atoms which surround them and so they may remain attached to the boundary and merely retard its movement. The magnitude of this retarding force is calculated and the condition under which the boundary can become detached from the bubbles is evaluated. Detachment occurs most readily from bubbles of a critical size and under conditions where there is a large driving force for grain boundary movement. The smallest bubbles move sufficiently rapidly that they tend to remain attached to the boundary, whereas the largest bubbles, for a given spacing, have greatest effect in impeding grain boundary mobility. Their effect is compared and contrasted with that of boundary pinning by solid precipitates. The analysis is used to interpret observations of the behavior of fission gases after grain boundary movement.

23,707 COHERENT ANNEALING TWIN BOUNDARIES AS VACANCY SINKS by R.L. Segall (U. Melbourne); Acta Met., Vol. 12, pp. 117-119(L), Jan. 196

Transmission electron microscopic studies on quenched gold has revealed that a coherent annealing twin boundary also acts as a very effective vacancy sink. It is suggested that vacancies cluster preferentially at the twin boundary similar to the segregation of impurities at stacking faults. The possibility of pre-existing monatomic steps in the coherent twin boundaries serving as vacancy sinks is also considered likely.

23,708 TRIGONS ON A TWIN BOUNDARY by A.R. Patel(Sardar Vaillabbha Vidyapeeth, India); Physica, Vol. 30, pp. 505-508, Mar. 1964

On a twinned region of a natural octahedral face of diamond a number of trigon pairs have been observed. These trigons on the two sides of the twin boundary are oppositely oriented. The figures formed due to these trigon pairs appear to be either parallelogram shaped or six sided (hexagons). It is conjectured that these trigon pairs might have been formed due to etching of dislocations on the twin boundary. How etching of a single dislocation on a twin boundary produces a parallelogram shaped figure while etching of an array of dislocations along the twin boundary produces a six sided figure is explained by drawing schematic diagrams. The implications are discussed.

23,709 X-RAY DIFFRACTION STUDY OF TWIN WALLS OF NiO SINGLE CRYSTALS by K. Kohn and S. Iida (U. Tokyo); J. Phys. Soc. Japan, Vol. 19, pp. 344-350, Mar. 1964

Twin walls in NiO single crystals have been studied with the Lambot X-ray diffraction technique. The amounts of tilt at some twin walls were in good agreement with the value expected theoretically in a simple twin structure, but in other cases they were quite different. It is concluded that twin walls are sometimes connected with crystalline lattice irregularities. Tilts of about 1′ are observed as a fine structure of the diffraction pattern, which suggests the presence of magnetostriction of about 10^{-4} in NiO. Dislocation density of as-cleaved and annealed crystals were estimated to be 10^{8-9} and less than 10^6 cm^{-2} respectively.

23,710 A GENERAL METHOD FOR CALCULATING ELECTRON-DIFFRACTION PATTERNS CONTAINING TWIN REFLECTIONS IN ISOMETRIC CRYSTALS by O. Johari and G. Thomas (U. California); Trans. Met. Soc. AIME, Vol. 230, pp. 597-599, Apr. 1964

A general crystallographic method for calculating twin reflection positions for isometric crystals is described. This method, when combined with stereographic projection and electron-microscopy techniques, is extremely useful in studies of twin structures. Consideration is made of pairs of points in reciprocal space, each pair having 180 degree rotation about the twin axis. The matrix of the transformation is obtained from the coordinates of three such pairs of points. From this matrix, the indices of any other point in reciprocal space can be determined. Transformations obtained from matrices for {111} twinning in fcc metals and {112} twinning in bcc metals are discussed. This general method has been verified for twinning in explosively deformed copper.

23,711 THE EFFECT OF INTERSTITIALS ON MECHANICAL TWINNING IN BODY-CENTERED CUBIC METALS by J.O. Stiegler, C.K.H. DuBose and C. J. McHargue (Oak Ridge Lab.); Acta Met., Vol. 12, pp. 263-264(L), Feb. 1964

Dislocation configurations in 500 ppm C doped Nb and pure Nb foils deformed at 78°K and subsequently annealed at 1000°C for one hour have been observed by a transmission electron microscope. The type, amount, and distribution of interstitials in these systems has been determined from the twinning behavior of the system. Discrepancies in earlier results are thought to arise from nonconsideration of the distribution.

23,712 MICROSTRAINING IN POLYCRYSTALLINE NIOBIUM by T.J. Koppenaal and P.R.V. Evans (IIT Res. Ctr.); J. Inst. Metals, Vol. 92, pp. 238-241, Apr. 1964

The early stage of plastic deformation in polycrystalline niobium at room temperature has been investigated using a strain sensitivity of 1×10^{-6}. Variables studied include grain size, prestraining, and strain-ageing. In the annealed or "locked" dislocation condition, the 1×10^{-6} yield stress is 11.2-15.6 kg/mm^2, depending upon the annealing treatment, while this yield stress is only 3.2-3.6 kg/mm^2 for specimens in the prestrained or "unlocked" dislocation condition. Observations of slip lines and dislocation etch pits in the micro-

train region of annealed specimens, indicate that grain-to-grain deformation occurs readily before the upper yield-point stress is reached.

Glide in Ge - See 24,522

23,713 CRACK INITIATION IN THE ZINC-MERCURY EMBRITTLEMENT COUPLE by A.R.C. Westwood (Martin Co); Phil. Mag., Vol. 9, pp. 199-209, Feb. 1964

For truly brittle crack initiation - in which the crack initiation energy is less than or equal to the true surface energy of the fracture plane - it can be shown that

$$(\sigma_{F_{A-B}} / \sigma_{f_A})^2 = \eta_{I_{A-B}}$$

where $\sigma_{F_{A-B}}$ is the fracture stress of coarse-grained specimens of solid metal A when exposed to liquid metal B; σ_{f_A} is the flow stress of specimens of metal A when tested in an inert environment; and $\eta_{I_{A-B}}$, the coefficient of embrittlement for crack initiation for the couple A-B, is defined as the ratio of the energies required to separate atoms across the fracture plane of metal A in the presence and absence of embrittling liquid metal B. Using this relationship in conjunction with studies of the flow and fracture behavior of polycrystalline zinc of various grain sizes tested in the amalgamated and unamalgamated conditions, $\eta_{I_{Zn-Hg}}$ was found to be 0.60 ± 0.04 at 298°K. This value is identical with the coefficient of embrittlement for cleavage crack propagation, $\eta_{P_{Zn-Hg}}$, previously determined for this couple - probably because in zinc, both crack initiation and propagation occur in the same atomic plane.

23,714 ANISOTROPIC GROWTH OF CLEAVAGE CRACKS IN IRON-3% SILICON SINGLE CRYSTALS by M. Gell and W. Robertson (Yale U.); Acta Met., Vol. 12, pp. 108-111(L), Jan. 1964

Cleavage cracks arising from hydrogen precipitation in excess of lattice solubility in {100} planes of Fe-3% Si have been studied to provide information on crack shape, direction of propagation and volume of plastic deformation due to crack growth. The shape of cleavage cracks in bcc crystals has symmetry characteristics. The direction of propagation reflects the anisotropic properties of Fe-Si. The crack easy direction was along <100>.

23,715 FAULTED STRUCTURES AND BRILLOUIN ZONE INTERACTIONS IN GOLD-BASED ALLOY SYSTEMS by T.B. Massalski (Mellon Inst.) and H. King (Imperial Coll., England); Acta Met., Vol. 12, pp. 106-108(L), Jan. 1964

Faulted structure and Brillouin zone interactions in hcp ζ-phase Au-Cd alloys are discussed. Complex structures in Au-based alloys cannot be explained solely on the basis of Brillouin zone-Fermi surface interaction; such an interaction is not a general phenomena in other systems. Uncertainties in lattice spacing data in Au-Cd for alloys containing less than 32 at. % Cd are thought to be due to the coexistence of ordered and disordered regions arising from previous heat treatment.

23,716 THE THERMAL ACTIVATION OF SLIP IN NEUTRON IRRADIATED COPPER by M.J. Makin (A.E.R.E., Harwell); Phil. Mag., Vol. 9, pp. 81-98, Jan. 1964

The activation energy and activation volume of a slip process in which dislocations cut obstacles by a combination of stress and thermal activation can be obtained at any temperature by measurements of the local temperature and strain rate dependence of the flow stress. Results are given of such measurements at 77°K and 293°K on neutron irradiated copper crystals in both the as-irradiated condition and after a mild annealing treatment (306°C for 251 min). Constant values of $(\partial \ln \sigma/\partial T)_{\dot{\epsilon}}$ and $(\partial \ln \sigma/\partial \ln \dot{\epsilon})_T$ were obtained during stage I of the deformation process at each temperature, enabling a single activation energy to be calculated. At the end of stage I, $(\partial \ln \sigma/\partial T)_{\dot{\epsilon}}$ and $(\partial \ln \sigma/\partial \ln)\dot{\epsilon}_T$ decrease to the unirradiated values, the decrease being sudden at 293°K. In both materials the activation energy and volume are temperature dependent, being much greater than 293°K than at 77°K. This temperature variation is considerably reduced by the annealing treatment, which affects principally the results at 77°K.

IMPURITIES

23,717 ANALYSIS OF IMPURITIES IN SOLID STATE ELECTRONIC MATERIALS by J. O'Connor (Tracer Lab.); Final Rept., Oct. 1, 1963, 28 pp., Contract AF19 604 7463, Proj. 4608; U.S. Gov. Res. Rep., Vol. 39, p. 126(A), Apr. 20, 1964 AD 428 785 OTS $3.60

Use of gamma ray spectrometry greatly increases speed and flexibility of activation analysis. A detailed separation scheme is given for determination of Fe, Cu, P and Ni in Si using ion exchange. Nondestructive analysis of Cr in lasers and masers and Ga in YIG by activation analysis are described. A study of elution of Cu (II) from Dowex 1 resin is presented.

23,718 SPECTROPHOTOMETRIC DETERMINATION OF CHROMIUM CONCENTRATION IN RUBY by D.M. Dodd, D.L. Wood and R.L. Barns (Bell Lab); J. Appl. Phys., Vol. 35, pp. 1183-1186, Apr. 1964

A spectrophotometric method for determining the concentration of Cr in oriented and unoriented single ruby crystals is described which makes use of the absorption coefficients for the blue and green bands and for the red lines at ~300°K. The coefficients are based on concentration data obtained by three independent methods.

23,719 METALLOGRAPHIC AND DIFFERENTIAL THERMAL ANALYSES OF THE PURITY OF CERIUM by D. Etter and J. Selle (Monsanto Res.); Trans. Met. Soc. AIME, Vol. 230, pp. 591-593, Apr. 1964

Differential thermal analysis (DTA) and metallographic analysis are shown to be sensitive tools for the qualitative determination of the purity of cerium. High purity cerium from various sources varies widely in melting points and in the shapes of DTA curves. A definite correlation is noted between the melting point, amount of premelting, and the number of inclusions present in the material. As the melting point increases, the amount of premelting and the number of inclusions decreases. No apparent correlation is found between spectrographic and chemical analyses and the trends in either melting point or the amount of premelting.

23,720 COMMENTS ON THE THEORY OF CONTINUOUS ZONE MELTING by J.K. Kennedy (AF Cambridge Res. Labs.); Trans. Met. Soc. AIME, Vol. 230, pp. 243-244(L), Feb. 1964

The effects of the variation of parameters of the zone-void system on zone melting are discussed. Parameters such as zone length (l), heater length (h) and effective distribution coefficient (k) effect α and β ($\alpha = C_p/C_f$, $\beta = C_w/C_f$; C_p, C_w, and C_f are solute concentrations in product, waste, and feed, respectively).

23,721 THE PREPARATION OF HIGH-PURITY BORON VIA THE IODIDE by A.F. Armington, G.F. Dillon and R.F. Mitchell (AF Cambridge Res. Labs.); Trans. Met. Soc. AIME, Vol. 230, pp. 350-354, Mar. 1964

Present methods of boron preparation are discussed with emphasis on the iodide intermediate. Several methods of boron tri-iodide preparation were investigated, the most satisfactory method being the preparation from the elements. A yield of 60 per cent based on iodine is found for this method. Zone-refining, sublimation, distillation, and fractional-recrystallization results are given for the boron tri-iodide, with distillation producing the best results. Several methods of decomposition are also discussed. The purity of the resulting iodide boron approximates the purity of the best available bromide boron.

23,722 A SUPPLEMENT TO "THERMODYNAMICS OF IMPURITY DOPING REACTIONS IN VAPOR GROWTH OF Ge" by T. Arizumi and I. Akasaki (Nagoya U.); Japanese J. Appl. Phys., Vol. 3, pp. 87-93, Feb. 1964

Reduction yields of germanium iodides by hydrogen are largely governed by free energies of iodination of Ge. The experimental results on hydrogen reduction of GeI_4 suggest that Lever's free energy data are more plausible than those previously postulated by the author and that the disproportionation reaction of GeI_2 is predominant at 700°K in OTP. Both free energies of reduction of impurity iodides by Ge and reduction yields of their tri-iodides are calculated again. The experimental transfer ratios of some important impurities are of the same order as the reduction yields of impurity tri-iodes calculated from Lever's data.

23,723 THE DEPENDENCE ON DEPOSITION CONDITIONS OF THE DOPANT CONCENTRATION OF EPITAXIAL SILICON LAYERS by R. Nuttall (Ferranti Ltd.); J. Electrochem. Soc., Vol. 111, pp. 317-323, Mar. 1964

Methods of doping epitaxial Si layers produced by the hydrogen reduction of $SiCl_4$ are discussed, and a technique by which a constant concentration of dopant in the $SiCl_4$ vapor may be achieved is described. A function termed the conversion efficiency, η, is estimated for the various reactions taking place in the deposition cell, and the influence of various reaction conditions on η for several dopants are reported. The uniformity of dopant concentration in the epitaxial layers is discussed and methods for controlling the concentration gradient present at the substrate/epitaxial interface are indicated.

23,724 MATHEMATICAL TREATMENT OF COMPETITIVE SURFACE AND VOLUME DIFFUSION PROCESSES by H. Amar (Temple U.) and J.B. Drew (Franklin Inst. Labs.); J. Appl. Phys., Vol. 35, pp. 533-535, Mar. 1964

Equations are derived for the surface diffusion of atoms into a half-plane (the boundary of which is kept at constant concentration) under conditions in which atoms are simultaneously being lost into the bulk via a volume diffusion mechanism. Two coupled boundary valued problems arise which are solved by treating the volume diffusion as a perturbation. Methods of evaluating the coefficient D_s of surface diffusion are discussed. The final surface concentration S resulting from the parasitic effect of volume diffusion contains three leakage

terms. These terms have the effect of altering the time dependence of the concentration. This formulation is useful in interpreting surface diffusion data obtained in the high-temperature range.

23,725 NUMERICAL SOLUTION OF FUNCTIONAL EQUATIONS BY MEANS OF LAPLACE TRANSFORM. Part III. THE DIFFUSION EQUATION by R.E. Bellman, R.E. Kalaba and J. Lockett (RAND Corp.); Memo No. RM3974NIH, Jan. 1964, 14 pp.; Grant GM09608 02; U.S. Gov. Res. Rep., Vol. 39, p.85 (A), Apr. 20, 1964 AD 428 074 OTS $1.60

A new method for the numerical integration of the heat or diffusion equation is presented. This hinges on the numerical inversion of LaPlace transforms. One advantage over the usual finite difference schemes is that a small amount of computation yields the solution for large values of the time. Results of some computational experiments are presented together with the FORTRAN programs.

23,726 CONCERNING THE DETERMINATION OF INTRINSIC DIFFUSION COEFFICIENTS IN BINARY SYSTEMS by V. Ruth and G.W. Powell (Ohio State U.); Acta Met., Vol. 12, pp. 264-267(L), Feb. 1964

The relative advantages and disadvantages of using equations of Darken and Heumann to determine intrinsic diffusion coefficients of binary systems are discussed. The relationship between Heumann's and Darken's equations are described and it is observed that Heumann's method is more direct, simpler to apply and generally more useful than Darken's method to determine intrinsic diffusion coefficients.

23,727 PRECISION LAPPING DEVICE FOR THE DETERMINATION OF DIFFUSION COEFFICIENTS IN CERAMIC MATERIALS by H.J. DeBruin and R.L. Clark (Oak Ridge Labs.); Rev. Sci. Instr., Vol. 35, pp. 227-228(L), Feb. 1964

An inexpensive lapping device for the determination of self-diffusion coefficients of Be in BeO of 10^{-13} cm^2/sec is described. Measurement of a mean displacement of the diffusing particle of less than 10 μ has been made with this device. A limiting factor is the extent of surface defects in polycrystalline specimens.

23,728 DIFFUSION OF IMPURITIES DURING EPITAXY by W. Rice (Arizona State U.); Proc. IEEE, Vol. 52, pp. 284-295, Mar. 1964

The diffusion of impurities in both epitaxial layers and the substrate is considered. The differential equations and boundary conditions which describe the problems are derived and solutions are presented for both the idealizations of a semi-infinite substrate and the true thickness of the substrate. Several types of boundary conditions are considered. For the cases of diffusion of impurities with the substrate considered as semi-infinite, the results from digital computation are given in tabular and graphical form. The method of application of the information to the design and production of epitaxial structures is indicated. A comparison is made between the solutions accounting for diffusion during epitaxy and solutions for a rationalized situation in which diffusion is computed by simpler means, and the simpler method is shown to be unsatisfactory for epitaxial calculations.

23,729 EFFECT OF DISLOCATIONS ON THE DIFFUSION OF SOME ELEMENTS IN GERMANIUM by I. Feltyn' and U. Ertelis (Acad. Sci. Latvian SSR); Invest. on Dislocation Structures, pp. 7-22, Nov. 29, 1963, Trans. from Latvijas PSR Zinatnu Akad. Vestis, No.7, pp. 67-74, July 1963; STAR, Vol. 2, p. 503(A), Feb. 23, 1964 JPRS-22076; OTS-63-41255, $2.25

The effect of dislocations on the effective diffusion coefficients of Ga, In, As, and Sb in Ge has been investigated. Increases were observed in diffusion coefficients, and this condition is explained as being due to the formation of an atmosphere of impurity ions and vacancies in the vicinity of dislocations where there exist favorable conditions for operation of the vacancy mechanism of diffusion.

23,730 EFFECT OF LOCAL ELECTRIC FIELDS ON THE DIFFUSION OF ANTIMONY IN GERMANIUM by G.I. Boltaks and T.D. Dzhafarov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2061-2065, Apr. 1964

The effect of the local electric field created by a concentration gradient of In or Ga on the diffusion of Sb in Ge has been investigated. It is shown that if the concentration gradients of the donor and the acceptor are directed in opposite directions, the electric field accelerates the displacement of the diffusing Sb ions. However, if these concentration gradients are co-directional the field retards the diffusion of Sb.

23,731 THE SURFACE DIFFUSION OF GERMANIUM ON COPPER by P.G. Shewmon and J.Y. Choi (Carnegie Inst. Tech.); Trans. Met. Soc. AIME, Vol. 230, pp. 449-453, Apr. 1964

The surface-diffusion coefficient for Ge^{68}, D_s (Ge), has been measured on (111) and (100) surfaces of Cu from 1000° to 620°C. D_s (Ge) on the (111) is two to three times that on the (100) as was found earlier for Cu and Au on Cu. D_s (Ge) on both (111) and (100) is about thirty times that found for Au or Cu tracers on the same surfaces, while in the temperature range where both D_s (Ge) and D_s (Au) have been measured the activation energy for Ge is the same as that for Au. The apparent activation energy for D_s (Ge) is not a constant, but decreases with temperature.

23,732 DIFFUSION KINETICS STUDIES IN THE Al-Ni-U SYSTEM by R.A. Harlow and O. Gamba (Atomics Intl.); Nov. 30, 1963, 35 pp., Contract AT (11-1)-GEN-8, NAA-SR-8387; STAR, Vol. 2, p. 352(A), Feb. 8, 1964 OTS $0.75

A diffusion couple technique has been developed and standardized for the purpose of obtaining meaningful data regarding the diffusion kinetics of the Al-Ni-U system. In addition, the Ni barrier bond between type 1100 Al cladding and cast U-3.5% Mo fuel alloy was metallographically examined on four fuel cylinders fabricated according to Piqua procedure. The following conclusions were obtained: (1) the penetration of Al into Ni followed a parabolic relationship with time; (2) the Ni penetration data generated by the diffusion couple technique were slightly higher than those derived from the cylinder bond study; (3) a low-Al phase AlNi or $AlNi_3$ nucleated at the Al_3Ni/Al_3Ni_2 interface when the supply of additional free Al into the system was restricted due to void formation or separation between intermetallics and Al; and (4) the interdiffusion rate of U and Ni also followed the parabolic relationship with time.

23,733 DIFFUSION OF ANTIMONY ON THE SURFACE OF GERMANIUM by P.V. Pavlov and V.A. Panteleev (Lobachevskii Gor'kii State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1058-1060, Nov. 1963

The surface diffusion of antimony has been studied on lapped and chemically polished surfaces of Ge over a temperature range of 250-650°C, and also on a Ge surface covered with an oxide film at 350°C. The temperature dependence of the diffusion coefficients found for the lapped and polished surfaces is

$$D_s, \text{ lapped} = 6 \times 10^{-6} \exp -(12{,}600/kT) \ cm^2/sec$$
$$D_s, \text{ polished} = 4 \exp -(38{,}700/kT) \ cm^2/sec$$

and the value of D_s for diffusion of Sb in an oxidized Ge surface at 350°C is $D_s = 7 \times 10^{-12}$ cm^2/sec.

23,734 DIFFUSION OF TANTALUM IN SINGLE-CRYSTAL GERMANIUM by V.I. Tagirov and A.A. Kuliyev; Oct. 7, 1963, 7 pp., FTD MT63 107; Trans. from Izv. Akad. Nauk Azerbaydzhanskoy SSR, Seriya Fiziko-Matematich. i Tekhnich. Nauk, No.1, pp. 65-68, 1962; U.S. Gov. Res. Rep., Vol. 39, p. 101(A), Apr. 20, 1964 AD 428 546 OTS $1.10

23,735 DIFFUSION OF BORON INTO SILICON by S. Maekawa and T. Oshida (Kobe Kogyo); J. Phys. Soc. Japan, Vol. 19, pp. 253-257, Mar. 1964

The diffusion of boron into silicon has been investigated over a temperature range from 1100°C to 1300°C with constant source conditions. True concentration profiles of boron diffusion layers were obtained by means of activation analysis by proton irradiations and conductivity measurements in order to understand the anomaly of apparent diffusion coefficients calculated from usual p-n junction methods. In the case of low surface concentration less than 6×10^{19}/cc the boron distributions are represented as error function complement, whereas at higher surface concentrations they show more convex distribution. The fast diffusivity in the high concentration region is attributed to the enhanced diffusion by induced lattice strain.

23,736 PHOSPHORUS NITRIDE AS A DIFFUSION SOURCE FOR SILICON by T.J. La Chapelle and H.B. Heller (Pacific Semicon.); Trans. Met. Soc. AIME, Vol. 230, pp. 311-314, Mar. 1964

Phosphorus nitride has been used as a diffusant for introducing phosphorus into silicon under various conditions. It has a temperature-dependent rate of decomposition beginning in the 500°C range, increasing very rapidly above 1000°C, producing gaseous phosphorus and nitrogen. Best control was obtained with a two-temperature arrangement, with silicon at the proper higher diffusion temperature. It is an easier compound to use than the usual P_2O_5 because it is nonhygroscopic and yields temperature-controlled surface concentrations together with excellent final surfaces. Surface doping nearly as high as that produced by phosphorus pentoxide has been observed for sources at 850° to 900°C. Reproducible high sheet resistances were obtained by using slow flow rates (1 linear in. per min) and staggered-baffle gas mixing with the nitride at 550°C. Both inert gas (argon, nitrogen) and oxidizing ambients have been examined. Oxygen reacts to produce anhydrous P_2O_5, consuming the source at a rapid rate. Nitrogen, except for short diffusion times, suppressed the dissociation reaction and sometimes produced inferior surfaces. Argon appears to be a more useful ambient.

23,737 DIFFUSION OF Cd IN CdS by H.H. Woodbury (GE Res. Lab.); Phys. Rev., Vol. 134A, pp. A492-498, Apr. 20, 1964

The self-diffusion of Cd in CdS has been measured under a variety of doping and firing conditions. Under saturated Cd pressure the diffusion coefficient is given by $D = 3 \exp(-2.0 \text{ ev}/kT)$. Under sulfur pressure at 800°C the diffusion coefficient is found to be linearly dependent on the donor-impurity concentration. A new mechanism for diffusion is proposed to explain the results. No evidence for interstitial Cd was observed and it is suggested that Cd and sulfur vacancies (Schottky defects) are the dominant native defects in CdS.

23,738 DIFFUSION IN GaAs by L.R. Weisberg (RCA Labs.); Trans. Met. Soc. AIME, Vol. 230, pp. 291-296, Mar. 1964

The general properties of diffusion in GaAs are reviewed. A total of fourteen atoms have been studied to date, and activation energies for eleven reported are (in ev): Ga(5.6), As(10), Zn(2.49), Cd(2.43), Sn(2.5), Mn(2.75), S(4.0), Se(4.2), Ag(0.33), Cu(0.52), and Li(1.0). The diffusion of the first eight atoms established the principle of sublattice diffusion for both host and impurity atoms, since atoms substituting for gallium have lower activation energies than those substituting for arsenic. The diffusion constant of interstitial copper has been determined for the first time by Hall and Racette using heavily doped p-type samples in which interstitial copper predominates. The anomalous behavior of zinc, which has an abrupt diffusion front and a strong dependence on zinc concentration, has recently been quantitatively explained in terms of an interstitial-substitutional equilibrium-diffusion mechanism. Lithium and silver diffuse mainly interstitially, while the diffusion of phosphorus is complicated by the continual formation of GaP. Junction-migration measurements indicate different results than radiotracer techniques, and this is one problem that still remains, together with discrepancies in cadmium-diffusion results, and an unexplained dependence of impurity diffusion on arsenic pressure.

23,739 DIFFUSION PROBLEMS RELATED TO GaAs INJECTION LASERS by M.H. Pilkuhn and H. Rupprecht (IBM Watson Res. Ctr.); Trans. Met. Soc. AIME, Vol. 230, pp. 296-300, Mar. 1964

p layers on n-type substrates of GaAs have been prepared by diffusion of Zn into these substrates. Experimental details about the diffusion technique are presented. It is shown that inhomogeneity in the substrate doping level and crystal structure defects cause nonplanarity in the junction plane. These nonplanarities give rise to high threshold current densities. From incremental sheet-conductivity measurements the Zn profile is derived. Data about surface concentration and gradient of the Zn concentration at the junction are presented. Finally, some results of laser diodes, which were made of wafers with extremely planar diffusion fronts, are discussed.

23,740 DIFFUSION, SOLUBILITY, AND DISTRIBUTION COEFFICIENT OF ZINC IN GALLIUM ARSENIDE AND GALLIUM PHOSPHIDE by L.L. Chang (Stanford U.); Rept. Nos. 63 104, TR5104 1, Oct. 1963, 59 pp., Contract AF33 616 7726; U.S. Gov. Res. Rep., Vol. 39, p. 127(A), Apr. 20, 1964 AD 428 828 OTS $6.60

Radiotracer Zn^{65} was vapor diffused in GaAs and GaP single crystals in closed, evacuated quartz ampoules. The solubilities and diffusion profiles were obtained over the temperature range 700 to 1100°C. The solubility data were analyzed by assuming Zn-GaAs and Zn-GaP to be binary systems and considering the transfer of neutral Zn from the liquid to the solid where some Zn atoms become ionized acceptors. The solubilities and distribution coefficients of Zn in these two semiconductors were calculated as functions of temperature up to the melting point of the solvents. The experimentally measured diffusion profile exhibit a steep front for Zn in GaAs above 700°C and for Zn in GaP above 900°C. Applications of the Boltzmann-Matano method to these profiles shows that the diffusion coefficient is strongly concentration-dependent. A precise evaluation of this dependence was obtained from isoconcentration diffusions performed at a fixed temperature: 900°C for Zn in GaAs and 1000°C for Zn in GaP.

23,741 THE DIFFUSION OF ZINC INTO GALLIUM ARSENIDE TO ACHIEVE LOW SURFACE CONCENTRATIONS by H. Becke, D. Flatley, W. Kern and D. Stolnitz (RCA); Trans. Met. Soc. AIME, Vol. 230, pp. 307-311, Mar. 1964

Zinc diffusions in GaAs having surface concentrations as low as 5×10^{16} atoms per cu cm have been attained. A multiple-diffusion sequence is employed during which Zn enters the GaAs from a SiO_2 film in a solid-to-solid diffusion step. The technique is illustrated for the case of a Zn surface concentration of $\sim 1 \times 10^{17}$ atoms per cu cm and a junction depth of 1.2 μ. Radiotracer measurements of ~0.1 μ layers of GaAs are used to delineate the resulting profile. A diffusion coefficient for Zn in pyrolytically deposited SiO_2 is reported.

23,742 ZINC DIFFUSION IN GaAs THROUGH SiO_2 FILMS by S.R. Shortes, J.A. Kanz and E.C. Wurst, Jr. (Texas Instr.); Trans. Met. Soc. AIME, Vol. 230, pp. 300-306, Mar. 1964

Zinc diffusion into GaAs from the vapor phase through reactively sputtered SiO_2 films has been investigated for various Zn pressures at 1000°C. Diffusions were carried out in evacuated quartz ampules with elemental zinc and with various Zn-Ga alloys. Sputtered films have proved effective in lowering surface concentrations and preventing surface deterioration during diffusion. Approximate complementary error-function impurity distributions were found when surface concentrations were reduced to approximately $3 \rightarrow 4 \times 10^{18}$ atoms cm^{-3} or less with dilute Zn sources or by diffusion through SiO_2 films. Zn diffusions in GaAs through SiO_2 films produced more planar diffusion fronts than were observed with uncoated wafers under identical conditions.

23,743 DIFFUSION OF SULFUR, SELENIUM AND TELLURIUM IN GALLIUM ARSENIDE by T.H. Yeh (IBM); J. Electrochem. Soc., Vol. 111, pp. 253-255 (L), Feb. 1964

A technique for diffusing n-type impurities (S,Se,Te) into p-type GaAs to form mesa p-n-p transistors is described. A thin layer of SiO evaporated onto the GaAs surface prevents the formation of Ga_2S_3, Ga_2Se_3 or Ga_2Te_3 compounds. Compound formation takes place only above a critical value of concentration of group VI elements.

23,744 DIFFUSION AND SOLUBILITY OF SILVER IN GALLIUM ARSENIDE by B.I. Boltaks and F.S. Shishiyanu (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1680-1684, Feb. 1964

The results of an investigation of the diffusion and solubility of silver in gallium arsenide in the temperature range 500-1160°C are reported. They indicate the existence of two diffusion flows due to the difference in conditions of the material close to the surface and in the bulk of the specimens. The maximum solubility in the surface region varies from $\sim 7 \times 10^{19}$ to $\sim 4 \times 10^{20}$ cm^{-3} and that in the bulk of the specimen from $\sim 2 \times 10^{17}$ to $\sim 8 \times 10^{17}$ cm^{-3}.

23,745 RAPID OXYGEN DIFFUSION IN BERYLLIUM OXIDE by S.B. Austerman and R.A. Meyer (Atomics Intl.); Nov. 30, 1962, 16 pp., Contract AT (11-1)-GEN-8; STAR, Vol. 2, p. 916(A), Apr. 8, 1964 NAA-SR-7637 OTS $0.50

Previous data on oxygen diffusion in polycrystalline BeO showed two separable regions of diffusion kinetics, and also indicated a third region of very deep, but low-magnitude, penetration by diffusant O^{18}. This deep penetration is verified and is regarded as being due to a rapid diffusion process. In addition, there appears to be a slight, but detectable, intrusion of H_2O^{18} vapor into grain boundaries at a particular stage of sample preparation.

23,746 GRAIN-BOUNDARY DIFFUSION IN MgO by B. Wuensch and T. Vasilos (AVCO); J. Am. Ceramic Soc., Vol. 47, pp. 63-68, Feb. 21, 1964

Grain-boundary diffusion of Ni^{2+} has been investigated in polycrystalline MgO and also in isolated grain boundaries in natural and prepared bicrystals of MgO. Concentration distributions were determined with the aid of both electron microprobe analysis and X-ray absorption analysis. Results from diffusion couples in which a surface was maintained at constant concentration during diffusion annealing indicate that grain-boundary diffusion is the predominant transport mechanism in polycrystalline MgO at temperatures below 1700°C. Lattice diffusion becomes increasingly important at higher temperatures and eventually becomes the dominant mechanism. Grain-boundary diffusion in MgO is not confined to a layer of atomic dimensions but extends over a zone of the order of microns. The activation energy for grain-boundary diffusion is less than that for lattice diffusion and is between 1 and 2 ev.

23,747 THE DIFFUSIVITY OF CARBON IN GAMMA IRON-COBALT ALLOYS by R.P. Smith (U.S. Steel); Trans. Met. Soc. AIME, Vol. 230, pp. 476-480, Apr. 1964

The diffusivity of carbon in iron, cobalt, and alloys of 89.7 and 79.3 wt pct Co has been determined by a decarburization method for the temperature range 850° to 1100°C. The plots of log D vs 1/T for the two Fe-Co alloys are linear through the region of the Curie temperature, showing that, unlike some cases of substitutional diffusion, carbon diffusion in these alloys is not affected by electron spin order.

23,748 DIFFUSION OF CHROMIUM IN NICKEL by S.P. Murarka, M.S. Anand, and R.P. Agarwala (AE Estab., Bombay, India); J. Appl. Phys., Vol. 35, pp. 1339-1341, Apr. 1964

Diffusion of chromium in pure nickel has been studied by radioactive tracer and residual activity techniques. The diffusion coefficient (in units of cm^2/sec) in the range 600°-900°C is given by $D_{Cr/Ni} = 0.03 \exp(-40{,}800/RT)$ and in the range 350°-600°C is given by $D_{Cr/Ni} = 5.45 \times 10^{-9} \exp(-13{,}700/RT)$. The bimodal diffusion behavior has been explained on the basis of solid solubility of chromium in nickel, which falls very rapidly from 1000°C downwards. The entropy of activation for high-temperature diffusion falls very well on the entropy vs activation energy curve for lattice diffusion in nickel.

23,749 DIFFUSION OF IRON INTO SINGLE-CRYSTAL MgO by S.L. Blank (U. California, Berkeley); Nov. 15, 1963, 33 pp., Contract W-7405-eng-48; STAR, Vol. 2, p. 628(A), Mar. 8, 1964 UCRL-11073, OTS $0.75

MgO single crystals were packed in iron powder and heated in a vacuum at

1150°, 1250°, and 1350°C. Concentration-vs-penetration profiles were determined by using the electron microprobe analyzer. The interdiffusion coefficient D is found to be concentration dependent in the range 1 to 22 at.% Fe. The apparent activation energy for diffusion increases with the iron concentration.

23,750 DIFFUSION OF IRON INTO SODIUM DISILICATE GLASS by M.P. Borom (U. California, Berkeley); Nov. 12, 1963, 44 pp., Contract W-7405-eng-48; STAR, Vol. 2, p. 749(A), Mar. 23, 1964 UCRL-11116, OTS $1.00

Diffusion couples of elemental iron and degassed sodium disilicate glass rod were prepared under neutral to reducing conditions at several temperatures and at varying times. The diffusion profiles were analyzed by using electron microprobe techniques. Diffusion-coefficient calculations and activation-energy determinations, indicated that a change in mechanism was occurring between 1000° and 1050°C. An indication is given by the magnetic-susceptibility measurements that atomic iron is the diffusing species at 900°C and that ferrous iron is the diffusing species at 1050°C. These observations are supported by transmission-spectroscopy measurements and by theoretical thermodynamic considerations. A discussion of the possible mathematics of the diffusional processes is given.

23,751 CONTRIBUTIONS TO THE THEORY OF DISCONTINUOUS PRECIPITATION by M.S. Sulonen; Acta Polytech. Scandinavica, Series No.28, Helsinki, 1964, 20 pp., pp. 5-20

A new theory is presented for the driving force of discontinuous precipitation. The driving force is ascribed to the stress energy arising from a steep change in the lattice dimensions of the vanishing matrix in a narrow diffusion zone forming ahead of the cell interface. To test the theory, the response of the discontinuous precipitation process to external tension has been studied in Cu-Ag, Cu-Mg, Ag-Cu, Pb-Sn and Zn-Cu alloys. It is shown that the directionality appearing in cell interface migration under tension is in agreement with predictions that can be made regarding the interaction of the external and diffusion zone stresses, and thus the theory is supported.

23,752 ON THE THEORY OF CELLULAR PRECIPITATION by J.S. Hirschhorn and R.A. Gregg (Pratt and Whitney); Acta Met., Vol. 12, pp. 120-122(L), Jan. 1964

A study of cellular precipitation has been made to evaluate the theory developed by Turnbull. Interfacial precipitation represents the behavior of a mobile cell-matrix interface. This type of precipitation was only found in specimens annealed at or above 0.6 of the liquidus temperature. Under such conditions short circuit diffusion paths become less effective when compared to volume diffusion. The rate controlling step under such conditions is found to be the transformation of precipitates along the interface into cell lamellae.

23,753 PRE-PRECIPITATION RATE IN Al-10% Zn ALLOY NEUTRON-IRRADIATED AT 78°K by S. Ceresara and T. Federighi (Ist. Speriment. Metal. Leggeri, Italy) and F. Pieragostini (SORIN); Phil. Mag., Vol. 9, pp. 623-633, Apr. 1964

The effect of a neutron irradiation at 78°K on the rate of pre-precipitation in Al-10% Zn alloy has been investigated by means of resistivity measurements. From the interpretation of the results it appears that whereas interstitial-type defects do not produce clustering of Zn atoms, during the recovery of vacancy-type defects an appreciable initial enhancement in the rate of clustering process is detected, depending on the thermodynamic state of the alloy. However, due to rapid elimination of the defects, after a certain ageing time, the rate of the process in an irradiated alloy becomes slower than in a quenched alloy.

Precipitation of C in Fe - See 23,971

23,754 PRECIPITATION OF NITRIDES IN IRRADIATED α-Fe by J.T. Stanley (Oak Ridge Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 284(A), Mar. 1964

The effect of irradiation upon the precipitation of nitrogen from solid solution in α-Fe has been studied by means of internal friction measurements. Although irradiation doesn't change the jump rate of nitrogen in α-Fe, the rate of precipitation is enhanced by a factor of about five. This enhanced rate of precipitation is attributed to the formation of nucleation sites during the irradiation. The enhancement effect saturates after a fast-neutron dose of 3×10^{15} neutrons/cm^2. The nature of the radiation-produced nucleation sites is not known but the saturation effect apparently eliminates displacement spikes from consideration. Wagenblast and Damask found that carbon becomes trapped on defects produced by irradiation. This effect has not been observed for the case of nitrogen in iron but cannot be definitely eliminated because of the lower total doses obtained in the experiments.

23,755 STUDY ON PRECIPITATES IN OXYGEN-DOPED SILICON SINGLE CRYSTALS BY X-RAY DIFFRACTION MICROGRAPHY by K. Furusho (Electrical Commun. Lab., Tokyo); Japanese J. Appl. Phys., Vol. 3, pp. 203-207, Apr. 1964

The effects of heat-treatment on oxygen-doped silicon single crystals have been studied by X-ray diffraction micrography using extinction contrast. For silicon crystals of 1×10^{18} atoms/cm^3 oxygen-concentration, characteristic intensity increases were observed after heat-treatment at 1000°C for several hrs and individual images were resolved after heat-treatment at 1200°C for a few hrs. From variation in the shape of images with diffracting planes, it was concluded that the images were due to the disc-shaped precipitates of silicon oxide parallel to {111} planes.

23,756 INCOHERENT IMPURITY PRECIPITATES IN MAGNESIUM OXIDE by B. Henderson (AE Res. Estab., Harwell); Phil. Mag., Vol. 9, pp. 153-159, Jan. 1964

Observations of incoherent impurity precipitates in magnesium oxide single crystals are reported. The possible chemical form of these precipitates, as indicated by selected area electron diffraction patterns obtained, is discussed.

23,757 ELECTRON MICROSCOPE STUDIES OF URANIUM DICARBIDE PRECIPITATES IN URANIUM CARBIDE SINGLE CRYSTALS by B.L. Eyre and M. J. Sole (AE Res. Estab., Harwell); Phil. Mag., Vol. 9, pp. 545-556, Apr. 1964

A method for preparing thin films of UC single crystals containing UC_2 precipitates is described. The films have been examined by transmission electron microscopy,and using selected area diffraction techniques the crystallographic relations between the UC_2 and the UC matrix have been established. Twinning is observed in the UC_2 precipitates and this is attributed to the interactions which occur when UC_2 crystals of different orientation intersect. A mechanism is proposed for the formation of UC_2 in slightly hyperstoichiometric UC.

CRYSTAL GROWTH

GENERAL

23,758 GROWING OF CRYSTALS AND AN INVESTIGATION OF THE KINETICS OF THEIR FORMATION by L.M. Belyayev and A.A. Chernov; Mar. 21, 1963, 20 pp., Trans. from Kristallografiya, Vol. 7, pp. 659-663, Oct. 5, 1962; STAR, Vol. 2, p. 89(A), Jan. 8, 1964 JPRS-18257; OTS-63-21377, OTS $0.50

The most important problem in crystallization is felt to be in the area of the formation of defects and of defective crystals. Work on this problem is divided into three areas: (1) investigation of the rise of crystals, (2) investigation of the shift of the phase boundary, and (3) the study of the mechanism and kinetics of the rise of defects. The following tasks and methodological questions are discussed: (a) the rise of crystals of the breadth of the metastable area in phase diagrams, (b) the speed of growth and the multiplicity of forms and properties of crystals of identical chemical composition, and (c) the problem of the rise of metastable conditions during the process of phase transformation when there are sufficiently large deviations from equilibrium.

23,759 INCOMPLETE LIQUID MIXING IN CRYSTAL GROWTH FROM THE MELT by W.R. Wilcox (Aerospace Corp.); J. Appl. Phys., Vol. 35, pp. 636-643, Mar. 1964

The boundary-layer treatment of Burton, Prim, and Slichter for prediction of segregation in crystal growth from the melt is extended to arbitrary binary solid-liquid equilibrium phase behavior. The validity of the quasi steady-state approach is examined by derivation of the initial transient. In many cases this transient is appreciable and must be considered for accurate predictions. Eigenvalues for calculation of the transient are given, along with a sample calculation.

23,760 SPHERULITIC CRYSTALLIZATION FROM THE MELT. Part I. FRACTIONATION AND IMPURITY SEGREGATION AND THEIR INFLUENCE ON CRYSTALLINE MORPHOLOGY by H.D. Keith and F.J. Padden, Jr. (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 1270-1285, Apr. 1964

A systematic study of impurity segregation in spherulitic crystallization is described. The experiments deal principally with high polymers, in which the role of "impurities" is fulfilled by stereoirregular molecules or by molecules of low molecular weight. It is shown that these species are rejected preferentially by growing crystals and that their diffusion plays a vital part in governing overall morphology. In particular, openness of texture is related to the concentration of impurity present; and coarseness of texture, which is a measure of the "diameters" of crystalline fibers between which impurities become concentrated during crystallization, is determined by $\delta = D/G$, where D is the diffusion coefficient in the melt and G is the radial growth rate of the spherulite. Results provide substantial support for a theory of spherulitic crystallization proposed by the authors.

23,761 SPHERULITIC CRYSTALLIZATION FROM THE MELT. Part II. INFLUENCE OF FRACTIONATION AND IMPURITY SEGREGATION ON THE KINETICS OF CRYSTALLIZATION by H.D. Keith and F.J. Padden, Jr. (Bell Lab.); J. Appl. Phys., Vol. 35, pp. 1286-1296, Apr. 1964

The influence of impurity segregation on the kinetics of spherulitic crystallization is examined. Radial growth rates over a range of temperatures are reported for a number of polymers containing various proportions of impurity species of widely varying molecular weight. Variations of growth rate with molecular weight indicate that transport processes within regions extending some distance from solid-liquid interfaces play a major part in controlling growth kinetics. In the unusual case of a polymer containing impurities of very low molecular weight, extended radial diffusion of impurities may even give rise to parabolic growth [(radius) $\propto$ (time)$^{1/2}$] in place of linear growth as normally found. Conventional interpretations fail to account satisfactorily for dependence on molecular weight, and are clearly inadequate in that they deal with transport processes only as "jump" processes at these interfaces. Complications that transport processes within the body of the melt introduce into the problem of formulating an absolute theory of growth kinetics are discussed.

23,762 GOVERNING EQUATIONS FOR THE SHAPES OF MOLTEN ZONES by R.E. Green, Jr. (Johns Hopkins U.); J. Appl. Phys., Vol. 35, pp. 1297-1301, Apr. 1964

Theoretical consideration is given to the equation governing the shapes of molten zones when they are not necessarily surfaces of revolution. This equation is seen to reduce to equations previously given for both vertical and horizontal molten zones when the shape is a surface of revolution. Solution of the equation governing the shape of the vertical molten zone when it is a surface of revolution gives corrected values for the maximum stable zone lengths for large rod radii. Detail consideration is given to the influence of a surface film on vertical zone stability.

23,763 THE MOTION OF LIQUID ALLOY ZONES ALONG A BAR UNDER THE INFLUENCE OF AN ELECTRIC CURRENT by D.T.J. Hurle, J.B. Mullin and E.R. Pike (Royal Radar Estab.); Phil. Mag., Vol. 9, pp. 423-434, Mar. 1964

A critical examination is made of the interpretation of experiments reported by Pfann et al. (1957) in which molten alloy zones were observed to move along the surface of a germanium bar through which a current was passed. It is shown that the influence of the Peltier effect alone cannot account for all of their experimental results and an alternative interpretation is proposed in which the motion is ascribed to a combination of the Peltier effect and ionic migration in the molten alloy. A theory is presented which yields an expression for the steady velocity of a thin zone under the influence of a temperature gradient, Peltier, Thomson and ionic migration effects. Certain special cases are considered and a new method of measuring differential ionic mobility is proposed.

23,764 EPITAXIAL GROWTH: AN ANNOTATED BIBLIOGRAPHY by H.M. Abbott and J.V. Kerrigan (Lockheed Aircraft); Report No. 6 90 63 42, Apr. 1963, 69 pp., Special Bibliography SB63 32; U.S. Gov. Res. Rep., Vol. 39, p. 64(A), Mar. 5, 1964 AD 419 558 OTS $7.60

This compilation contains 169 selected references and a preface on epitaxial crystal growth. Included are such factors as crystal growth and formation, vapor growth, twinning, and thin film processes.

23,765 EPITAXIAL DEPOSITION OF SEMICONDUCTOR MATERIALS: AN ANNOTATED BIBLIOGRAPHY by C.L.M. Blocher, M. Bloomfield and T.J. Lyndon (Hughes Aircraft); Oct. 1963, 68 pp.; STAR, Vol. 2, p. 24(A), Jan. 8, 1964 LS-BIB-63-3

This bibliography covers references on the epitaxial growth of semiconductor materials. The bibliography has been divided as follows: (1) general articles on the theory and techniques of epitaxial deposition and survey articles, (2) germanium, (3) silicon, (4) deposition for both germanium and silicon, and (5) other semiconductor materials.

23,766 RECENT ADVANCE OF ENGINEERING RESEARCH AT THE RESEARCH INSTITUTE OF ELECTRICAL COMMUNICATION. Part II by K. Nagai (Tohoku U.); Rept. Res. Inst. of Electrical Commun., Tohoku U., Vol. 15, No. 2, pp. 1-6, 1963

Synthetic crystal growth techniques are described for crystals of interest in the field of electronics. A hydrothermal method of producing quartz crystals has been developed utilizing precipitation of quartz from a supersaturated solution of sodium carbonate. Silicon single crystals have been grown by the floating zone technique and by gaseous epitaxial growth; in the latter method, projection of an ultraviolet ray onto a silicon substrate reduces the temperature required for gaseous epitaxial growth. Germanium single crystals have been grown by a new method dependent on liquidus epitaxial growth; germanium dissolves in molten bismuth (at temperature T_1) and diffuses to an upper region (temperature $T_2 \rightarrow T_2 < T_1$) where it deposits on a seed crystal floating on the surface. Many other synthetic crystals have been grown for use in piezoelectric, ferroelectric, and maser applications.

23,767 MECHANISM FOR CRYSTAL GROWTH DISCOVERED; Bell Labs. Rec., Vol. 42, pp. 142-143, Apr. 1964

A new fundamental mechanism of crystal growth, termed the vapor-liquid-solid (VLS) mechanism, has been discovered. VLS growth occurs when a droplet composed of a saturated solution of a crystalline material and an impurity receives atoms from a vapor and deposits these atoms at the interface between the droplet and substrate. As the process continues, the droplet becomes displaced from the substrate crystal and rides atop the growing whisker. The VLS mechanism can be applied to most crystalline substances. The crystals are near-perfect and can be grown at temperatures much lower than those required for current vapor-phase crystal growth processes.

23,768 VAPOR-LIQUID-SOLID MECHANISM OF SINGLE CRYSTAL GROWTH by R.S. Wagner and W.C. Ellis (Bell Labs.); Appl. Phys. Lett., Vol. 4, pp. 89-90(L), Mar. 1, 1964

The vapor-liquid-solid (VLS) mechanism of crystal growth is discussed. The mechanism is proposed as the result of detailed studies of the morphology and growth of silicon whiskers. In this mechanism, an impurity must be present to form a liquid alloy droplet of relatively low freezing temperature. Because the droplet is a preferred site for deposition from the vapor, the liquid becomes supersaturated with silicon and the whisker grows by precipitation from the droplet. A screw dislocation is unnecessary because the whisker grows from the liquid. The VLS growthof Si whiskers with Au, Pt, Ag, Pd, Cu or Ni impurity is described. The factors that determine the selection of the impurity are outlined. The method is applicable to the growth of compound crystals, filamentary and macroscopic crystals and of epitaxial layers. P-N junctions and heterojunctions can be formed. The VLS mechanism explains observations made during the growth of α-Al_2O_3, SiC, and BeO crystals.

23,769 GETTER SPUTTERING FOR THE PREPARATION OF THIN FILMS OF SUPERCONDUCTING ELEMENTS AND COMPOUNDS by H.C. Theuerer and J.J. Hauser (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 554-555, Mar. 1964

A new sputtering technique which eliminates the need for ultrahigh vacuums in preparing thin films of materials sensitive to gaseous impurities is described. This technique uses the gettering action of part of the sputtered atoms to produce an atmosphere within an anode can very low in reactive gases such as O_2 and N_2. In consequence, contamination by such interstitial impurities is prevented during deposition. The method has been successfully used for the preparation of superconducting films of materials such as Ta, Nb, V_3Si, V_3Ge, and V_3Ga. This technique in conventional vacuum equipment produces films of pure elements with superconducting properties comparable to those of bulk material. The method should be applicable also to the preparation of magnetic alloy films and epitaxial semiconductor films where contamination by reactive gases has been a problem.

23,770 A HIGH INTENSITY CARBON-ARC IMAGE FURNACE AND ITS APPLICATION TO SINGLE CRYSTAL GROWTH OF REFRACTORY OXIDES by G. Goldsmitts, M. Hopkins and M. Kestigian (RCA Labs.); J. Electrochem. Soc., Vol. 111, pp. 260-262(L), Feb. 1964

A high intensity carbon arc furnace capable of growing refractory materials at temperatures of 3300°C is described.

23,771 CERAMIC DOUBLE CELL FOR CRYSTAL GROWTH BY FUSED SALT ELECTROLYSIS by W. Kunnmann and A. Ferretti (Lincoln Lab.); Rev. Sci. Instr., Vol. 35, pp. 465-466, Apr. 1964

A ceramic double cell for the electrolytic growth of single crystals is described. The cell is easily fabricated from low cost commercially available materials.

23,772 CYLINDRICAL HIGH TEMPERATURE, HIGH PRESSURE APPARATUS by W.J. Witteman and T. Werkman (NV Phillips); Rev. Sci. Instr., Vol. 35, pp. 461-465, Apr. 1964

A cylindrical high pressure apparatus which can be used in the pressure range of up to 100,000 atm and for temperatures of up to 1500°C is described. The high pressures are generated by means of a pressurized rubber tire acting on three identical segments. Each segment is provided, near the center of the apparatus, with a tungsten carbide cylinder. The high pressures are transmitted to the surfaces of a pyrophyllite sample holder when the three tungsten carbide cylinders with parallel axes are brought together. The high pressure calibration was based on the observed linear relationship between the water pressure in the tire and the transition points of, respectively, bismuth, thallium, and barium. It turns out that the pressure is practically independent of the axial coordinate. A thin-walled graphite cylinder with a wall thickness of 0.1 mm, used for heating purposes, is placed along the axis of the sample holder. This graphite cylinder is insulated from the sample by means of boron nitride, and there was no difficulty in making separate contacts for the furnace and the sample. Temperature indication during the operation of the apparatus was obtained by measuring the resistance of p-type germanium. In the testing of this apparatus at higher temperatures, up to 1500°C, synthetic diamonds of about 0.3 mm were produced.

23,773 SELF-SUPPORTING HIGH TEMPERATURE HEATERS by E.L. Hansen (Sandia); Rev. Sci. Instr., Vol. 35, p. 242(L), Feb. 1964

A compact heating element for heating small areas in vacuum or a controlled atmosphere to 1000°C is described. The element consists of two Mo spiral units, wound with the same pitch but in opposite direction. The spiral units are assembled one inside the other and are spot welded at the point of intersection.

23,774 THE PERFORMANCE OF A SMALL ROTATING SUBSTRATE HOLDER FOR VACUUM DEPOSITION by C.D. Hopkins, R. Jacobsson and L. Thiessen (Inst. Optical Res., Stockholm); J. Sci. Instr., Vol. 41, pp. 167-168, Mar. 1964

The performance of a small and simple rotating substrate holder for simultaneous deposition on several substrates is studied. It is shown to give thickness variations of about 0.4 per cent over a substrate area with diameter of 20 mm.

SEMICONDUCTOR CRYSTALS

23,775 A MECHANISM CAUSING SUPERSATURATION OF IMPURITIES DURING SEMICONDUCTOR CRYSTAL GROWTH by K. Lehovec (Sprague Electric); Surface Sci., Vol. 1, pp. 165-170, Apr. 1964

The concentration of impurities in growing semiconducting crystals is a function of a space charge layer potential adjacent to the surface of the crystal. Considerable supersaturations may occur in crystals such as Ge(In) or Ge(Sb). Local melting may result when a volume element from the surface passes into the bulk of the crystal beyond the space charge layer. It is suggested that this phenomenon may account for the occurrence of fundamental striations.

23,776 DISPLACEMENT SPIKE CRYSTALLIZATION OF AMORPHOUS GERMANIUM DURING IRRADIATION by J.R. Parsons and R.W. Balluffi (U. Illinois); J. Phys. Chem. Solids, Vol. 25, pp. 263-272, Mar. 1964

Thin films of metastable amorphous germanium (700 ± 100 A thick), prepared by evaporation on rocksalt, were bombarded with either fast neutrons or monoenergetic Xe^+ ions at room temperature. Subsequent examination by bright and dark field transmission electron microscopy revealed that small discrete crystallized regions (ranging up to several hundred A in size) were produced throughout the amorphous matrix by the irradiation. The fast neutron irradiation resulted in a linear increase in the density of crystallized regions with neutron doses ranging from 0 to 5.1×10^{16} n cm^{-2} and a most probable crystallized region size of 190 A. The monoenergetic Xe^+ ion bombardment (covering a range of incident energies) resulted in a most probable crystallized region size very closely equal to the calculated ion range for incident ion energies from 40 to 90 kev. Also, a low (< 40 kev) and a high ($\geq$ 140 kev) Xe^+ ion energy cutoff for the production of crystallized regions were observed. Other furnace annealing experiments with similar amorphous films showed that they crystallized completely near 400°C as a result of ordinary homogeneous heating. The results are explained on the basis of "displacement spike crystallization," where the concentration of kinetic energy in the displacement cascade region is capable of inducing crystallization of the amorphous structure. Experimental evidence is presented which indicates that the crystallization is confined to the displacement cascade region and therefore requires the intense atomic agitation characteristic of the early stages of a displacement spike.

23,777 WEB GROWTH OF SEMICONDUCTORS by S. O'Hara and A.I. Bennett (Westinghouse Res. Lab.); J. Appl. Phys., Vol. 35, pp. 686-693, Mar. 1964

A novel process for growth of diamond-lattice semiconductors is described, and a model is proposed for the growth mechanism. For germanium the process yields extended thin flat sheets, typically 1 cm wide and 0.1 mm thick, of good crystalline quality and relatively flat {111} surfaces. The sheet, or web, freezes from a liquid film drawn up by surface tension between two coplanar dendrites which originate from a single seed and are grown from the melt simultaneously with the sheet. Resistivity throughout the sheet is quite uniform. Etching of Ge webs shows them to be essentially dislocation-free and does not reveal any microsegregation of impurities. Si and InSb have also been grown in this manner. The proposed model postulates that although the dendrites at either side of the web grow beneath the melt surface in usual dendritic fashion, the faces of the web itself normally have no extension below the melt surface. The exterior contact angle between the solid and liquid surfaces is less than 180° but greater than the equilibrium contact angle which would be observed if the flat faces extended beneath the melt surface. In spite of this the grown faces are plane and vertical, thickening of the web being restricted by difficulty of nucleation. In this respect the predictions of this model are significantly different than for Czochralski or floating-zone growth. Extensive experimental observations, including deliberately produced irregularities, verify the predictions of the model.

23,778 SILICON FREE GALLIUM ARSENIDE [in German] by R.K. Willardson; Elektron. Rund., Vol. 18, pp. 93-94, 97, Feb. 1964

Problems in the production of GaAs for device materials (such as pulling techniques) are reviewed and the interrelation between semiconductor properties and purity is briefly discussed.

23,779 APPARATUS FOR OBTAINING HOMOGENEOUS INGOTS by F. Houzvicka, S.G. Parker and O. Wilson (Texas Instr.); Rev. Sci. Instr., Vol. 35, pp. 276-278, Mar. 1964

An apparatus was built for casting several homogeneous InSb ingots of identic composition. The resulting ingots made possible the study of zone refining pa rameters.

23,780 PREPARATION OF FINE-GRAINED PbTe BY ULTRASONIC AGITATION OF A SOLIDIFYING MELT by M. Weinstein (Tyco); Trans. Met. Soc. AIME, Vol. 230, pp. 321-328, Mar. 1964

A technique for preparing fine-grained lead telluride by ultrasonic agitation a solidifying melt is described. Material prepared by this technique is dense and chemically homogeneous. N-type PbTe, containing 0.03 mole pct PbI_2, has been made and its thermoelectric properties have been measured as a funct tion of temperature. For comparison, the properties of similarly doped PbTe made by cold pressing and sintering, and by extrusion, have also been measured. The ultrasonically prepared material compares favorably with the others in its thermoelectric-efficiency factor. Comparison of compressive-flow curve for the three kinds of PbTe show that the ultrasonically prepared material has much superior ductility. The cleavage strength of the ultrasonic material is re lated to the grain size, D, by the Petch relation: $\sigma_c = \sigma_o + kD^{1/2}$. Extrapol tion to infinite grain diameter yields a fracture strength of 5000 psi for single crystal PbTe.

Preparation of SnTe - See 23,833

23,781 PREPARATION AND ELECTRICAL PROPERTIES OF SILVER ANTIMONY TELLURIDE by R.A. Burmeister and D.A. Stevenson (Stanford U.); Trans. Met Soc. AIME, Vol. 230, pp. 329-332, Mar. 1964

Single-phase silver antimony telluride has been prepared by zone-melting tec niques using initial compositions of $(Ag_2Te)_{0.41} - (Sb_2Te_3)_{0.59}$. A new phase ap pears upon prolonged annealing of this material, but the reaction does not ap pear to be a simple eutectoid decomposition. A complete analysis of the phase equilibria is complicated by the slow kinetics involved. The Hall coefficient, magnetoresistance, electrical resistivity, and Seebeck coefficient are all sen sitive to the presence of second phases. The low Hall mobilities measured for single-phase material indicate that the usual band theory is inadequate to explain the observed transport properties in the system. Density anomalies of up to 2.5 pct between measured and theoretical density were observed but are nc conclusive evidence for a defect structure.

Growth of ZnSb - See 23,939

23,782 ACTIVE THIN FILM PROGRAM by M. Macha (Lear Siegler); Aug. 22 1963, 38 pp., Contract NObsr87634, Proj. SR008 03 03; U.S. Gov. Res. Rep Vol. 39, p. 61(A), Apr. 5, 1964 AD 427 338 OTS $1.25

Techniques for vacuum evaporation single crystal semiconductor films of Ge and/or Si on insulating substrates are discussed. Basic feasibility studies of th films for use as active circuit elements in microelectronic assemblies, techniq for controlled doping, and fabrication of prototype elements and assemblies to prove feasibility of the processes and compatibility with vacuum deposited pas sive elements were included.

23,783 GROWTH OF EPITAXIAL SILICON LAYERS BY VACUUM EVAPORATION. Part I. EXPERIMENTAL PROCEDURE AND INITIAL ASSESSMENT by G.A. Unvala and G.R. Booker (U. Cambridge, England); Phil. Mag., Vol. 9 pp. 691-701, Apr. 1964

Epitaxial Si layers have been grown on single crystal Si substrates by the vacu um evaporation method. The apparatus and experimental procedure used are described, and an initial assessment of the layers is given. The growth was markedly dependent on the deposition rate. In particular, when the rate was increased beyond a certain critical value, no stacking-fault defects occurred in the layers.

23,784 TECHNIQUES FOR FABRICATION OF LARGE, THIN, SILICON SINGLE CRYSTALS by W.B. Nowak, R.D. French and E.C. Steeves (Northeaste U.); Res. in Energy Conversion, pp. 1-30, Nov. 22, 1963; STAR, Vol. 2, p. 17(A), Apr. 8, 1964 AD 429 505

Apparatus for producing silicon films by vapor deposition and by vacuum evaporation looking to the fabrication of large single-crystal films for solar cells (1 to 10 microns thick, about 60 cm^2 area) is described. $SiCl_4$ in H_2 at one atmosphere pressure was used in the vapor deposition; work-accelerated electron beam heating and a Silicon carbide anode with a deep well were used in the vacuum evaporation at about 10^{-5} torr. Fabrication techniques under investig

tion are nonepitaxial and include whole-surface exposure to the silicon atoms, planar edge-growth in the solid state, planar crystallization, and planar zone melting. Substrate testing has shown: (1) BN may be suitable if the spalling can be eliminated. (2) Mo is unsuited because of rapid interaction. (3) Liquid Sn is unsuited for vapor deposition because of the rapid formation of $SnCl_2$. (4) Films of unknown composition form on liquid NaCl and fluid glass during vapor deposition, thus intercepting the silicon deposit.

Growth of Si Films - See 23,571

23,785 SINGLE-CRYSTAL GERMANIUM FILMS BY MICRO-ZONE MELTING by J. Maserjian; Solid State Electron., Vol. 6, pp. 477-484, Sept.-Oct. 1963

A technique has been developed for growing single-crystal Ge films in situ on a dielectric substrate. An electron beam is used to melt a small zone of polycrystalline Ge films. Single-crystal growth is induced by electrically scanning the beam in a preferred manner over a selected region of the film. An additional heat source maintains the surrounding film at elevated temperatures in order to avoid excessive temperature differentials. The scanning pattern employed permits a randomly nucleated crystallite to seed the surrounding growth. In this manner, a single crystal, the order of a millimeter across, can be grown in a chosen location. Larger crystals should be possible with larger beam deflections. This work has been largely confined to film thicknesses of 3μ to 10μ and to substrates of sapphire. Sapphire was used because its coefficient of thermal expansion closely matches that of Ge and because of other desirable properties. All films were deposited by vacuum evaporation. The technique is logically extendable to other materials that can be grown in vacuum.

23,786 DEVELOPMENT OF IMPROVED SINGLE CRYSTAL GALLIUM PHOSPHIDE SOLAR CELLS by W.O. Groves and A.S. Epstein (Monsanto); Qtrly. Rept. No.2, Sept. 12-Dec. 12, 1963, 63 pp., NASA Contract NAS3-2776; STAR, Vol. 2, p. 540(A), Mar. 8, 1964 NASA CR-55311, OTS $6.60 ph, $2.09 mf

Single-crystal gallium phosphide has been prepared by epitaxial deposition on single-crystal gallium arsenide using hydrogen chloride in an open-tube vapor transport process, with excess phosphorus and either gallium or gallium phosphide sources. Crystal growth rate, structure, and purity are discussed. Doping with tellurium and zinc has been demonstrated. Solar-cell characteristics measured at room temperature have generally fallen into two categories: (1) high open-circuit voltage and low short-circuit current densities; (2) low open-circuit voltages and high short-circuit currents. In the former group of cells, an open-circuit voltage of 1.18 volts has been achieved with a short-circuit-current density of ~0.1 ma/cm². In the latter category, cells having a short-circuit-current density as high as 5 ma/cm² have been obtained with open-circuit voltages around 0.7 volts. These cells have their main spectral response at wavelengths of the order of 0.7 μ whereas cells of category (1) respond more to the band edge absorption.

23,787 CHEMICAL EQUILIBRIA IN THE GERMANIUM-IODINE AND GERMANIUM-BROMINE SYSTEMS BY WEIGHT-LOSS MEASUREMENTS by F. Jona, R.F. Lever and H.R. Wendt (IBM Watson Res. Ctr.); J. Electrochem. Soc., Vol. 111, pp. 413-417, Apr. 1964

Simple heterogeneous equilibria can be elucidated by determining the total amount of solid that goes in the gas phase under the action of a known amount of gaseous solvent at a given temperature. This method was first tested satisfactorily with the germanium-iodine system, for which thermodynamic data are already available, and then applied to the germanium-bromine system. The data make it possible to calculate the ratio between total density of germanium atoms and total density of halogen atoms in the gas phase within a wide range of temperatures and pressures. These calculations enable one to predict the direction and the amount of diffusive vapor transport in closed or open vapor-growth systems.

23,788 MICROSCOPIC OBSERVATION OF FILM CROSS SECTIONS HAVING STEEP CONTOURS by B.R. Frieden (U. Rochester); Appl. Optics, Vol. 3, pp. 395-398, Mar. 1964

A new method is proposed for microscopic observation of the thickness distribution across the thick (greater than about 12 μ) transparent film. The quality of an observation is analyzed by expressing the constants of the thickness distribution. Constraints are derived governing design of the viewing system by algebraically demanding that the resolution error be sufficiently small, and the image intensity and focal depth be sufficiently large. The constraints upon system parameters seem to be physically realizable.

Growth of Si Whiskers - See 23,768

METAL CRYSTALS

23,789 A STUDY OF THE GROWTH AND PERFECTION OF SINGLE CRYSTALS OF THE RARE EARTHS AND ALKALI METALS by J.F. Kirn (Virginia Inst. for Sci. Res.); Jan. 31, 1963, 23 pp., Grant AF AFOSR61 41, AFOSR J1355; U.S. Gov. Res. Rep., Vol. 39, p. 26(A), Mar. 20, 1964 AD 426 565 OTS $3.60

Single crystals of sodium and potassium were prepared by the Czochralski techniques in glass vessels under vacuum or an argon atmosphere. Methods of cutting, orienting, and studying the samples microscopically were developed. Chlorinated hydrocarbons show considerable promise as etchants. An arc-image furnace was constructed and single crystals of nickel were prepared.

23,790 SINGLE CRYSTALS GROWN BY THE BRIDGMAN-METHOD IN PROTECTIVE ATMOSPHERE by P. Kettunen and J. Forsten (Finland Inst. Tech.); Acta Polytech. Scandinavica, Series No.28, Helsinki, pp. 6-22, 1964

Single crystals of aluminum-copper, copper and molybdenum-iron have been grown by the ordinary Bridgman-method, using either argon or hydrogen as protective gas. Difference in orientation of the growing copper crystals was effected by changing the maximum temperature and growth rate. Influence of the impurities in the melted material was observed in three different ways: first of all by the X-ray spots being split at the upper end of the crystal, proving that the impurity concentration there was greater than at the lower end; secondly, at the upper ends of the oxygen-free-high-conductivity copper crystals, there was found a star pattern figure which was absent in the purer copper crystals; thirdly, in aluminum crystals there was found a periodic structure of alternating regions of high and low impurity concentration.

23,791 ELIMINATION OF SMALL-ANGLE BOUNDARIES IN HIGH-PURITY ZINC CRYSTALS GROWN FROM THE MELT by C.K. Chyung and W.E. Taylor (Michigan State U.); J. Appl. Phys., Vol. 35, Part 1, pp. 731-732, Mar. 1964

Zinc single crystals have been grown by improving the soft-mold technique. To prevent dislocations present in the seed from propagating into the crystal bulk, an S-shaped constricted region (offsetting) was machined between the seed and the blank. The crystals were free from sub-boundaries, except some local polygonization with a linear dislocation density of 1 to 5 x 10^3 cm^{-2}, or 5 to 25 sec of arc. Total dislocation density was counted to be 4 to 9 x 10^4 cm^{-2}.

23,792 RAPID-FREEZE METHOD FOR GROWTH OF BISMUTH SINGLE CRYSTALS by S. Fischler (Lincoln Lab.); Trans. Met. Soc. AIME, Vol. 230, pp. 340-341, Mar. 1964

Large striation-free single crystals of bismuth have been grown from the melt by rapid freezing. Zone-refined bismuth, together with doping impurities if desired, is placed in a shallow flat-bottomed graphite boat and melted in air with a propane hand torch. The torch is then withdrawn in a manner which causes the melt to freeze directionally. Crystallization, which requires only a few minutes, usually results in the formation of a single crystal even when a seed crystal is not used. Crystals of any desired orientation may be grown by using oriented seeds. Undoped crystals grown by this method have residual resistivity ratios ($\rho_{300°K}/\rho_{4.2°K}$) greater than 200.

23,793 GROWTH OF WHISKERS DUE TO SOLID-TO-SOLID PHASE TRANSFORMATION IN ZIRCONIUM by M.M. Nieto (Cornell U.); J. Appl. Phys., Vol. 35, p. 461(L), Feb. 1964

The growth of whiskers from 0.15 mm diameter zirconium wire was studied. Tests were made by (1) cycling the temperature about the α-β transition temperature, (2) hanging weights on the wire, and (3) varying the pressure. A model is discussed in terms of the experimental results.

23,794 PRESSURE INDUCED GROWTH OF METAL WHISKERS by C.H. Pitt and R.G. Henning (U. Utah); J. Appl. Phys., Vol. 35, pp. 459-460(L), Feb. 1964

The rate of growth of tin whiskers has been studied as a function of pressure. It was found that growth rate decayed with increasing time and decreasing pressure. Heavier cold work of the surface on which the whiskers were grown also increased the density of whiskers. Average growth rates varied from 76 A°/sec at 2670 psi to 195 A°/sec at 8000 psi.

23,795 GROWTH AND TRANSFORMATION CHARACTERISTICS OF COBALT WHISKERS by M.A. Gedwill, C.J. Altstetter and C.M. Wayman (U. Illinois); Trans. Met. Soc. AIME, Vol. 230, pp. 453-460, Apr. 1964

Cobalt whiskers have been grown by the hydrogen reduction of $CoBr_2$. The fcc ⇌ hcp martensitic transformation of these whiskers was studied using X-ray and metallographic techniques. Present theories of the fcc ⇌ hcp martensitic transformation are examined in the light of the present findings. Experimental evidence for slip as a part of the transformation mechanism is presented.

Growth of Fe Whiskers - See 23,569

23,796 OBTAINING MOLYBDENUM SINGLE CRYSTALS AND THEIR PROPERTIES by V.S. Yemel'yanov, A.I. Yevstyukhin, G.A. Leont'yev and A.N.

Semenikhin; Soviet Res. in Production and Phys. Met. of Pure Metals, Vol. 10, pp. 39-45, Jan. 1964; STAR, Vol. 2, p. 623(A), Mar. 8, 1964
JPRS-22697; OTS-64-21263, OTS $3.00

A method of growing molybdenum single crystals from the gaseous phase by thermal dissociation of $MoCl_5$ is described. Filaments up to 3-mm thick consisting of monocrystal segments up to 90-mm long were obtained. These crystals bent easily at room temperature, had a microhardness in the range 180 to 200 kg/mm^2 (200 gm load), a modulus of elasticity somewhat greater than ordinary molybdenum, and an internal friction which incrased monotonically from 1.6×10^{-5} at -190°C to 3.8×10^{-5} at 200°C. The effects of quenching and annealing of the single crystals on the internal friction were also investigated.

OTHER CRYSTALS

23,797 GROWTH OF SINGLE CRYSTALS OF COBALT OXIDE BY THE VERNEUIL METHOD by N.A. Velikhova (Acad. Sci. USSR); Soviet Phys.-Cryst., Vol. 8, pp. 643-645(L), Mar.-Apr. 1964

Growth of single crystals of cobalt oxide from charges of $Co(NO_3)_2 \cdot 6H_2O$, $CoSO_4 \cdot 7H_2O$ and $Co(NH_4)_2 \cdot 6H_2O$ is described. Experiments show that the use of $Co(NO_3)_2 \cdot 6H_2O$ to obtain a charge is not advisable. The crystal CoO displays perfect cleavage on {100}, and results show that the mosaic exists only at the surface. The presence of gas inclusions is characteristic of all crystals grown from charges which are obtained by firing of the cobalt nitrate. These inclusions cannot be avoided even by lowering the growth rate.

23,798 SINGLE CRYSTAL FILM OF FERRITES by H. Takei and S. Takasu (Tokyo Shibaura Electric); Japanese J. Appl. Phys., Vol. 3, pp. 175-178, Apr. 1964

Single crystal films of $NiFe_2O_4$, $CoFe_2O_4$ and $FeFe_2O_4$ have been prepared epitaxially by decomposing the respective metal halides with water vapor on the cleaved (100) surface of MgO crystal. The thickness of the film was varied over the range from several μ to about 100 μ by changing experimental conditions. X-ray diffraction analysis showed that the films were of spinel structure and the crystal axis was always parallel to that of MgO substrate. Ferromagnetic resonance measurement and chemical analysis of $NiFe_2O_4$ film suggested a slightly uneven distribution of the components along the direction perpendicular to the substrate surface.

23,799 FERROMAGNETIC COMPOSITIONS AND THEIR PREPARATION by T.A. Bither, Jr. (E.I. du Pont); U.S. Pat. 3,126,346, Issued Mar. 24, 1964

Methods for preparing new ferromagnetic compositions based on readily available components which exhibit a maximum saturation induction within a useful temperature range are presented. The desired dependence of magnetization on temperature can be achieved by varying the composition of the ferromagnetic product, which is obtained by heating mixtures of the elements to a temperature in the range of 600° to 1400°C. Examples of the production of these compositions using materials of usual commercial availability are given.

Preparation of:
$AgFeO_2$ - See 23,596
Ni-Fe-Cr Films - See 24,115

23,800 GROWTH OF CRYSTALS BY FLAME FUSION by A. Linz, E.F. Farrell, M.J. Redman, A. Berkebile and A. Vetrovs; Mol. Orbitals and Electron-Transfer Spectra in Rutile, Dec. 1963, 26 pp., Contract AF 33(616)-8353; STAR, Vol. 2, p. 914(A), Apr. 8, 1964

The application of the flame-fusion technique to the growth of various types of oxide crystals is reported. Details of the design of a three-tube coaxial post-mix oxyhydrogen torch with an efficient powder-feed mechanism are given, as well as feed preparation methods and growth conditions for a number of crystals, including Al_2O_3 (corundum), $(Al,Cr)_2O_3$ (ruby), Cr_2O_3, Y_2O_3, TiO_2, $SrTiO_3$, MnO, NiO, CoO, and (Ni,Co)O. The advantages and disadvantages of the flame-fusion method for various types of materials are discussed with relation to alternate methods.

23,801 CRYSTAL GROWTH AND MAGNETIC SUSCEPTIBILITIES OF SOME RARE-EARTH SODIUM MOLYBDENUM SCHEELITES by M. Schieber and L. Holmes (Harvard U.); J. Appl. Phys., Vol. 35, pp. 1004-1005, Mar. 1964

The composition range for growing tetragonal scheelite-type single crystals was investigated and located on the ternary diagram Gd_2O_3-MoO_3-Na_2O. Single crystals, the largest one weighing more than 1.2 g, and having a composition of $R_{0.5}Na_{0.5}MoO_4$, with R = Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, and Yb, were grown by slowly cooling the ternary melts from 1000°C with rates between 1.1°-3.2°C/h. The crystals were leached out of the flux by boiling them with NH_4OH. The various colored transparent pyramidal crystals have their tetragonal "c" axis perpendicular to the pyramidal base. The unit cell dimensions of the individual crystals are given. The magnetic susceptibilities of the scheelites of Gd and Dy are reported between 3° and 300°K. Dy or Gd scheelite did not show an ordinary ordering temperature above 1.8°K.

23,802 ZINC TUNGSTATE CRYSTAL GROWTH, DISLOCATIONS, AND CRYSTALLOGRAPHY by S. O'Hara (Westinghouse Res. Labs.); J. Appl. Phys., Vol. 35, pp. 1312-1316, Apr. 1964

Single crystals of zinc tungstate have been grown by the Czochralski method from melts prepared by various methods. Of the three chemical etches evaluated for purposes of revealing dislocations in this material, solutions of potassium or sodium hydroxides were most satisfactory. The (100) and (010) planes were shown to be slip planes. Both of these planes are parallel to the growth direction of crystals grown for maser applications. Annealing experiments indicated appreciable mobility of the dislocations at about 800°C. Etch pit counts revealed typical dislocation densities of 10^4-10^5 pits/cm^2 in areas near the center, and around 10^6 pits/cm^2 at outer regions of the crystal. Gaseous inclusions were frequently surrounded in their immediate vicinity by dislocations, and regions with a high density of these inclusions also had a high dislocation density. Some miscellaneous crystallographic information is also presented to enable crystals to be accurately orientated by simple optical methods.

23,803 CZOCHRALSKI GROWTH OF DOPED SINGLE-CRYSTAL LANTHANUM TRIFLUORIDE (LaF_3) FOR LASERS by M.A. Hiller and O.M. Stafsudd (NA Aviation); J. Appl. Phys., Vol. 35, pp. 693-695, Mar. 1964

A method of growing large, optically clear lanthanum trifluoride crystals has been developed. The method is quite simple and fast in that setup time per run is considerably shorter than that required by other growth methods.

23,804 BIG YIGS GROW IN SALT by J.W. Nielson (Airtron); Electronics, Vol. 37, pp. 44-45, Jan. 31, 1964

The production of yttrium-iron garnet (YIG) crystals for microwave filters and limiters is described. A molten-salt technique is used because of its ability to grow large, sound crystals up to 300 grams that exhibit desirable narrow linewidth characteristics (0.3 oe or less). Success depends on the use of large systems and good temperature control. Raw $Y_3Fe_5O_{12}$ crystals are cut into approximately cubic samples, reduced to rough spheres in a tumbling mill and polished to a high finish in race-type polishers.

23,805 GROWTH OF CRYSTALLINE INGOTS OF $BaTiO_3$ FROM THE MELT IN AN OXYGEN ATMOSPHERE by E.V. Bursian and N.P. Smirnova (Gertsen Leningrad State Inst.); Soviet Phys.-Cryst., Vol. 8, pp. 638-639(L), Mar.-Apr. 1964

A method for growing large single crystal or polycrystalline forms of $BaTiO_3$ is described. The dimensions of the crystalline ingots are limited only by the dimensions of the furnace. Ingots with dimensions of 22 x 8 x 1 mm were obtained, which have ε equal to $(1.1 \pm 0.2) \times 10^4$ at an optimum field intensity of 2.8 kv/cm and temperature of 20°C, and have a Curie temperature of (115 ± 2)°C. The volumetric conductivity of the ingots is of the same order as in ceramics of corresponding composition.

23,806 BARIUM TITANATE by S. Waku (NTT); Rev. Electr. Commun. Lab., Vol. 12, pp. 123-150, Mar.-Apr. 1964

A study of the ternary system of TiO_2-MgO-alkali earth oxides, which confirms the ferroelectricity of barium titanate, and a study of a barium titanate solid solution system are reported. Research was also carried out on the growth of barium titanate single crystals with the object of developing a ferroelectric storage element; the purity of materials, kind and quantity of impurities, and the effect of growing methods on the electric characteristics of single crystals were investigated. Dislocations of single crystals were successfully detected and that the relation between dislocation distribution and crystal growth could be clarified.

Crystallization of $BaTiO_3$ - See 23,893

23,807 SINGLE-CRYSTAL BORON FILMS ON SILICON by A.F. Armington, W.D. Potter and L.E. Tanner (AF Cambridge Res. Labs.); J. Appl. Phys., Vol. 35, Part 1, pp. 730-731(L), Mar. 1964

A laboratory method of preparing single-crystal boron halides on silicon single crystal substrates by the thermal reduction of BCl_3 is presented. This method resembles that of Theurer for the epitaxial growth of silicon from $SiCl_4$. The boron is deposited on 0.63-cm polished and etched silicon squares 100 μ thick producing boron films about 10 μ thick.

Growth of CdI - See 23,578

Preparation of Nb Carbides - See 23,590

Formation of NiC - See 23,534

Growth of UC Films - See 23,757

CRYSTAL SURFACES

23,808 THE PARABOLIC OXIDATION KINETICS OF ALPHA-ZIRCONIUM AT 850°C by G.R. Wallwork, W.W. Smeltzer and C.J. Rosa (McMaster U.); Acta Met., Vol. 12, pp. 409-415, Apr. 1964

An investigation is reported on the oxidation properties of alpha-zirconium at 850°C in oxygen for exposures extending to 400 hr. The kinetics were determined by volumetric and gravimetric techniques and may be represented for exposures to approximately 200 hr by the parabolic relationship:

$$\Delta M/A = (2.1 \times 10^{-5})\sqrt{t}\ g.\ O/cm^2.$$

Scale thicknesses and oxygen gradients in the metal were determined by metallographic techniques. It is demonstrated that parabolic diffusion relationships derived from an oxide-metal model account for the kinetics of oxidation, scale growth and oxygen solution in the metal.

23,809 STUDIES ON THE OXYGEN GRADIENTS IN OXIDIZING METALS. Part I. ZIRCONIUM by J.P. Pemsler (Kennecott Ledgemont Lab.); J. Electrochem. Soc., Vol. 111, pp. 381-385, Apr. 1964

The oxygen gradient beneath the oxide film on zirconium oxidized at 850°C for times ranging from 8 to 305 hr has been measured. The technique used involves the measurement of the rate of dissolution of interference colored oxide films. Experimentally determined gradients are in good agreement with a theoretical expression involving the diffusivity, time, and oxide film thickness. Metallography and microhardness measurements demonstrated the existence of a number of "phases" in the oxygen containing metal substrate. These are believed to be associated with order-disorder reactions. No evidence of zones of constant composition or steady-state gradients, as reported by previous investigators, were observed.

Oxidation of Al - See 23,570

23,810 ELECTRODE ASSEMBLY FOR ANODIZATION OF SEMICONDUCTORS by E. Banjamini and E. Duffek (Fairchild Semicon.); Rev. Sci. Instr., Vol. 35, pp. 237-238(L), Feb. 1964

An electrode assembly for anodizing single crystal Si slices is described. The assembly makes possible immersion of the Si anode into the electrolyte while allowing an electrical contact to the slice with minimum current leakage. Mechanical seals are used as a simple method of securing the semiconductor anode to the electrode assembly, eliminating special preparatory procedures required in other techniques.

23,811 AN APPARATUS FOR GRAVIMETRIC DETERMINATION OF THE EFFECTS OF LOW PRESSURE OXIDATION by R.W. Harrison and E.J. Delgrosso (Pratt and Whitney); J. Sci. Instr., Vol. 41, pp. 222-224, Apr. 1964

The design and capabilities of an apparatus for measuring small weight changes continuously during the oxidation of metals and alloys at oxygen pressures down to 0.1 μtorr are described. The oxidation specimen was connected to a calibrated spring, and its extension could be detected accurately by a magnetic transducer coupled to an amplifier and recorder, so that weight gain or loss could be measured to ± 0.1 mg. Control of the oxygen pressure for long periods of time is a most critical factor in this type of test. Proper control is achieved by an adjustable leak through a micrometer needle valve from an oxygen reservoir at 1 torr. As an example, niobium tested at 1200°C in oxygen at 10 μtorr was observed to increase in weight at a linear rate of 0.38 mg cm^{-2} h^{-1} over a ten-hour period.

23,812 THE INTERACTION BETWEEN GERMANIUM AND CUPRIC IONS IN AN AQUEOUS SOLUTION by M.J. Sparnaay (NV Philips); Surface Sci., Vol. 1, pp. 102-109, Jan. 1964

The reproducibility of the EMF values of the galvanic cell Ge/aqueous electrolyte/calomel is diminished by traces of cupric ions in the solution. This is especially the case at low pH values. This behavior is connected with the formation of surface states after introduction of cupric ions into the solution (Brattain and Boddy), together with an electrochemical reaction at the Ge/solution interface between cupric ions, germanium and water. In separate experiments, carried out with germanium powder which was brought in contact with solutions of known pH and known Cu^{2+}-concentrations, it appeared that cupric ions were discharged and hydrogen ions formed. This electrochemical reaction is reversible: addition of an acid leads to the re-formation of cupric ions whereby hydrogen ions are consumed and the reversibility is especially marked at low pH values. Electrochemical reactions of this type can be used to locate the value of the standard potential of the reaction between germanium and water.

Adsorption of O_2 on Diamond - See 23,572

23,813 CHEMISORPTION AND ORDERED SURFACE STRUCTURES by J.J. Lander (Bell Labs.); Surface Sci., Vol. 1, pp. 125-164, Apr. 1964

Results of low energy electron diffraction studies of a variety of surface structures formed by chemisorption are reviewed. Ordered structures and "superstructures," reconstructive first-order transitions and order-disorder phenomena are found to be common. Isotherms with a continuous dependence of coverage on pressure do not apply to such "single crystal" systems but may apply accidentally to the polycrystalline systems. The Fowler and similar isotherms are more appropriate but neglect important elements of the complex interactions producing first-order transitions accompanied by reconstruction of substrate atoms. Factors determining surface structures are discussed. These structures are a prolific source of 1D and 2D order-disorder phenomena with wide ranges of complexity. Activated adsorption and nucleation phenomena are probably common but sometimes go unnoticed when less direct techniques are used because of initial unactivated adsorption in relatively unstable states, or because the more stable states are not attained. All these phenomena have assumed a considerable importance rather abruptly because experimental substantiation has required direct measurement of ordered surface structures.

23,814 ADSORPTION PHYSICS OF METALLIC SURFACES PARTIALLY COVERED BY METALLIC PARTICLES. Part I. ATOM AND ION DESORPTION ENERGIES by J.D. Levine and E.P. Gyftopoulos (MIT); Surface Sci., Vol. 1, pp. 171-193, Apr. 1964

The desorption energies of atoms and ions for metallic surfaces partially covered by monatomic metallic particles are calculated theoretically based on the assumptions that the adsorbed particles consist of a single species held onto the surface by bonds that are partially ionic and partially covalent. The theoretical results are compared with available experimental data and very good agreement between theory and experiment is established. A unique feature of the derived formulas is that they do not involve any adjustable constants.

23,815 DESORPTION OF POTASSIUM FROM TUNGSTEN IN AN ELECTRIC FIELD by A.G. Haumovets (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1668-1674, Feb. 1964

It is shown that the results of experiments on field desorption of potassium from tungsten with no migration may be treated as evaporation of ions through a potential barrier, lowered by the Schottky effect. The surface diffusion rate of K atoms over W is very strongly dependent on the magnitude and direction of the electric field. Electron interaction between K atoms and tungsten is found strongest at faces of type {110}.

23,816 DESORPTION OF FLUORINE FROM MOLYBDENUM by C.H. Skeen (Atomics Intl.); J. Appl. Phys., Vol. 35, pp. 463-464, Feb. 1964

The repulsive potential energy per pair of adatoms and the heat of activation for the desorption of fluorine from the clean molybdenum surface have been measured. The values found are $(4.8 \pm 1.2) \times 10^{-4}$ ev and 6.3 ev, respectively. A model is developed and discussed in terms of the results.

23,817 THE EFFECT OF SOLID STATE DISLOCATIONS UPON THE CATALYTIC ACTIVITY OF METALS by T.D. Perkins, C.M. Sliepcevich and W.R. Upthegrove (Oklahoma U.); Final Rept. Mar. 1, 1963, 108 pp., Contract Nonr98208; U.S. Gov. Res. Rep., Vol. 39, p. 63(A), Mar. 5, 1964
AD 419 533 OTS $9.60

The effect of dislocations upon catalytic activity is discussed. The dislocation density, superficial surface area, microscopic surface area, and mass of a silver catalyst were measured, and the (211) plane of the metal was subsequently used to catalyze the decomposition of formic acid. Dislocation densities varied by plastically deforming the metallic catalyst ranged from 10^6 to 10^8 line intersections per cm^2. Decomposition rates for the formic acid reaction were measured over a temperature range of 165 to 190°C and a pressure range of 20 to 70 mm Hg. The effect of different dislocation densities upon catalytic activity was shown to be related to the change in hydrogen overpotential.

23,818 ABNORMAL THERMAL ETCHING BEHAVIOR IN A COPPER-SILICON ALLOY by M.B. Kasen and D.H. Polonis (U. Washington); Trans. Met. Soc. AIME, Vol. 230, pp. 602-603, Apr. 1964

An unusual thermal etching phenomenon has been observed on the surface of a Cu-Si alloy. Photomicrographs of a Cu-4.8 pct Si alloy heated at 525°C for 16 hours in an argon atmosphere illustrate preferential removal of Si from the matrix by oxidation, resulting in a surface which is completely a phase overlying an a plus structure. It is suggested that the microstructures reflect the diffusion of impurity atoms along extended dislocations within the a grains prior to surface oxidation. The observed phenomenon is therefore attributed to a balance between the kinetics of pipe diffusion and of the oxidation process under the particular experimental conditions.

23,819 VAPOR ETCHING OF GERMANIUM BY GERMANIUM TETRAIODIDE by S. Iida, Y. Sugita, and M. Nomura (Hitachi, Ltd.) Japanese J. Appl. Phys., Vol. 3, pp. 61-62, Jan. 1964

Vapor etching of a (111) germanium substrate crystal by GeI_4 vapor with hydrogen or argon gas is described relative to obtaining an uncontaminated flat surface for a well-deposited epitaxial layer. For mixtures of GeI_4 and H_2, etching rate is a linear function of mol fraction GeI_4 up to 0.006 mol fraction. The activation energy of the etching process is 9.3 kcal/mol for a mol fraction of 0.0055. Using argon as carrier gas, the activation energy for etching at a GeI_4 mol fraction of 0.00014 is 12.1 kcal/mol.

Etching of Dislocations in:
LiH_3SeO_2 - See 23,654
NaCl - See 23,655
$ZnWO_3$ - See 23,802

23,820 SURFACE DECORATION OF GERMANIUM AND SILICON by M. Inoue (Matsushita Electronics); Japanese J. Appl. Phys., Vol. 3, pp. 57-58 Jan. 1964

Real crystal surfaces are known to contain many or multiple atomic steps. Step edges are sites of preferential nucleation. Gold and carbon were deposited successively on cleaved and grown {111} surfaces of germanium and silicon and the arrangement of cleavage steps in germanium were made visible in an electron microscope as chains of gold particles. By using this decoration technique, the initial mode of growth for a silicon film grown epitaxially on a {111} plane was studied.

23,821 DECORATION OF FACETS ON SILVER by J.G. Allpress and J.V. Sanders (CSIRO, U. Melbourne); Phil. Mag., Vol. 9, pp. 645-658, Apr. 1964

The facets produced on silver by thermal etching have been investigated in detail by examining decorated replicas of them in an electron microscope. Gold, condensed on the surface in vacuum, forms perfectly oriented sheets on the complex facets which contain many kink atoms. By contrast, the gold condenses on {100} and {111} planes as separated, randomly distributed crystals with some preferred orientations. Atomic steps on these planes are decorated by preferential nucleation.

23,822 QUANTITATIVE DETERMINATION OF PREFERRED ORIENTATION by R.H. Bragg and C.M. Packer (Lockheed); J. Appl. Phys., Vol. 35, pp. 1322-1328, Apr. 1964

Solutions to the problems which usually prevent accurate X-ray determinations of preferred orientation are presented. The relationship between observed and corrected intensities and the angle dependent absorption factors are treated, including the case of displaced and distorted line profiles caused by low absorption in thick specimens. The absorption factors are derived experimentally from measurements of the scattered (Compton) background radiation without recourse to calculations or tables. Two simple methods, either by varying the wavelength λ or the order n of X-ray reflection, span the region of the pole figure in which data are unreliable or unobtainable if only one wavelength or order is used. Random samples are not required for normalizing the data to "times random" units. The intensity for a random sample can be calculated from the corrected data itself and the equation $s_{hkl} = [\int\int I_{hkl}(\alpha,\beta)\ \sin\alpha d\alpha d\beta]/2\pi$ where (α,β) are the coordinates of a point on the usual polar net. It is suggested that textures can generally be represented by Gaussian or superposition of Gaussian orientation distributions.

23,823 A NEW METHOD OF DETERMINING THE ORIENTATION OF CRYSTALS USING A WEISSENBERG GONIOMETER by W.A. Wooster (Brooklyn Crystall. Lab., Bottisham); J. Sci. Instr., Vol. 41, pp. 130-132, Mar. 1964

A method, involving the use of a Weissenberg goniometer, is described for finding the orientation of a crystal of known cell size and shape, when it is orientated arbitrarily on the goniometer head. A single photograph in the equi-inclination setting is taken and interpreted in terms of the positions of reflecting reciprocal points. A graphical method of finding the orientation of the crystallographic axes from the directions of the normals to the indexed lattice planes is given. This is illustrated by a practical example. Also the analytical procedure which can be employed in conjunction with a computer is described.

23,824 THE MEASUREMENT OF THE MISORIENTATION OF A CRYSTAL by W.A. Wooster (Brooklyn Crystall. Lab., Bottisham); J. Sci. Instr., Vol. 41, pp. 229-230, Apr. 1964

A method, particularly suited to large crystals, is described whereby the mis-setting of a crystal on an oscillation or Weissenberg goniometer may be determined from a single setting photograph. A graphical solution appropriate to the small angles involved is developed. The measurements of the positions of spots on a setting (oscillation) photograph are converted into coordinates of a straight line. From the intercepts of this line on its coordinate axes the angles defining the mis-setting may be determined. A practical example is given.

23,825 TECHNIQUE FOR ORIENTATION OF BICRYSTAL SEEDS by B. Addis and G. Bishop (Cornell U.); Rev. Sci. Instr., Vol. 35, p. 227(L), Feb. 1964

A technique for the rapid orientation of tilt bicrystal seeds by the use of the Laue back-reflection method is described. Although this technique is of special interest for orienting crystals grown by the Czochralski method, the equipment could be modified readily for techniques employing molds and also for growing tricrystals.

23,826 SPHERE GRINDING AND POLISHING by H. Belson (UNIVAC); Rev. Sci. Instr., Vol. 35, pp. 234-236(L), Feb. 1964

A grinding and polishing method for producing small, well polished, spherical samples of YIG using the resonance linewidth of the material as a test criterion is described. The method is a variation of the tumbling technique involving a tunnel with abrasive walls and a cross-sectional diameter 2-3 times the specimen diameter. Airjets drive the samples along the tunnel. 0.017 inch diameter samples have been produced using this method.

23,827 THE SPUTTERING OF COMPOUNDS by S.P. Wolsky, E.J. Zdanuk (Mallory Lab. Phys. Sci.) and D. Shooter (Raytheon); Surface Sci., Vol. 1, pp. 110-118, Jan. 1964

Sputtering yield data, atom ejection patterns, and sputtered film composition all support a molecular sputtering mechanism of GaSb. The surface structure models used to explain the atom ejection patterns are discussed. Selective sputtering of Ga was noted. Considerable information was obtained concerning the sputtering of diamond structure materials.

Getter Sputtering in the Preparation of Superconducting Thin Films - See 23,766

23,828 EVAPORATED METALLIC CONTACTS TO CONDUCTING CADMIUM SULFIDE SINGLE CRYSTALS by A.M. Goodman (RCA Labs.); J. Appl. Phys., Vol. 35, pp. 573-580, Mar. 1964

Vapor deposited metallic contacts (area $\doteq$ 1 mm^2) have been made to oriented conducting cadmium sulfide crystals. The metals employed were Al, Ag, Cu, Pd, Au, and Pt. The electrical properties of these contacts have been studied by measurements of: (1) differential capacitance as a function of bias voltage, (2) current-voltage characteristics, and (3) spectral variation of photoemission from the metal into the cadmium sulfide. These measurements have been analyzed to yield values of $\Delta\phi$ (work function of the metal with respect to the cadmium sulfide at the contact) that are reproducible from contact to contact for a given metal and different for different metals. The relationship between $\Delta\phi$, ϕ_m (work function of the metal in vacuum), and χ (semiconductor electron affinity), $\Delta\phi = \phi_m - \chi$, is confirmed to be consistent with $\chi \doteq 4.0$ volts for cadmium sulfide.

23,829 ELECTROPLATED GOLD AND COPPER CONTACTS TO CADMIUM SULFIDE by A.M. Goodman (RCA Labs.); Surface Sci., Vol. 1, pp. 54-70, Jan. 1964

Rectifying contacts have been prepared by electroplating gold and copper onto crystallographically oriented, single crystal, cadmium sulfide blocks. Differential capacitance, current-voltage, and photoelectric measurements were made in an attempt to determine $\Delta\phi$, the net work function of the metal with respect to the semiconductor at the contact. The differential capacitance measurements could be interpreted in terms of a unique value of $\Delta\phi$ for any given contact. However, neither the current-voltage measurements nor the photoelectric measurements could be easily interpreted in terms of the simple Bethe diode theory for a single value of $\Delta\phi$. It is concluded that there is good evidence for the existence of patches of different $\Delta\phi$ at plated gold and copper contacts to cadmium sulfide. The effective values of $\Delta\phi$ determined by the different measurements range from $\sim$0.75 to 1.2 volts for gold and from $\sim$0.6 to 0.8 volts for copper.

ENVIRONMENTAL EFFECTS

Monte Carlo Calculations on Defect Anneal - See 23,618

Annealing of:
Al - See 23,626
Rh - See 23,984

Irradiation Induced Defects in KBr - See 23,914

X-Ray:
Generation of F- and M-Centers in Alkali Halides - See 23,636
and Electron Irradiation Generation of F-Centers in KBr, KCl, LiF and NaCl - See 23,637
Induced:
F-Centers in KBr - See 23,642
Dislocations in NaCl - See 23,664

Neutron Damage in Si - See 23,615

Radiation Defects in CdS - See 23,617

Irradiation Direction Dependence of Defects - See 23,616

Irradiation Effects on:
- Ferroelectric Properties - See 23,898
- Magnetic Properties of:
  - Ferrites - See 24,111
  - Mo Permalloy and Fe - See 24,112
  - Permalloy Films - See 24,113
- Precipitation in Al-Zn - See 23,753

Displacement Spike Crystallization of Amorphous Ge During Irradiation - See 23,776

SOLID STATE PHYSICS

GENERAL

23,830 MODERN STUDY OF SOLIDS by J.D. Patterson (South Dakota Sch. of Mines and Tech.); Am. J. Phys., Vol. 32, pp. 269-278, Apr. 1964

This article attempts to present a modern viewpoint of solids from an elementary and yet fundamental point of view. The unifying concept used is that of the "particles" of solid-state physics. Electrons (with spin), holes, phonons, plasmons, and magnons are discussed. The interaction of these particles is discussed in experiments involving light absorption, X-rays, magnetic resonance, the Mössbauer effect, neutron scattering, electron beams, charge and heat transport, and acoustic absorption.

23,831 THE SOLIDIFIED INERT GASES by G. Boato (U. Genoa, Italy); Cryogenics, Vol. 4, pp. 65-75, Apr. 1964

The properties of solidified inert gases as typical molecular solids are reviewed. A survey of the properties is given at an elementary level, with emphasis on the determining effect of zero-point energy. Recent experimental and theoretical advances in the knowledge of lattice and thermal properties are reported, taking as a starting point the article by Dobbs and Jones on argon in 1957. It is shown that the Lennard-Jones 6-12 potential is adequate only for a first approximate description of lattice dynamics of solidified inert gases. There is a need for a more realistic potential if one wishes to make further progress in the theory. On the other hand, the theoretical models for describing point defects and their migration in inert gas crystals are thought not to be accurate enough, independently of the interaction potential which is chosen.

23,832 INVESTIGATION OF ALLOYS OF THE SYSTEM PbTe-SnTe by A.A. Machonis and I.B. Cadoff (NYU); Trans. Met. Soc. AIME, Vol. 230, pp. 333-339, Mar. 1964

The resistivity, Hall coefficient, Seebeck coefficient, and thermal conductivity have been measured as a function of temperature for cation-rich alloy single crystals covering the composition range across the PbTe-SnTe system. Alloying of PbTe with up to 20 pct SnTe was found to have little effect on the energy gap. Above 20 pct SnTe the alloys were "p" type but below this range the sign could be varied by heat treatment. The lattice thermal resistivity of the compounds SnTe and PbTe is raised by alloying one with the other. Z values in the order $2 \times 10^{-3}°K^{-1}$ for $Pb_{0.8}Sn_{0.2}Te$ at 140°K and $1.5 \times 10^{-3}°K^{-1}$ for $Pb_{0.7}Sn_{0.3}Te$ at 350°K were among the interesting values obtained.

23,833 EVIDENCE THAT SnTe IS A SEMICONDUCTOR by J.A. Kafalas, R.F. Brebrick and A.J. Strauss (Lincoln Lab.); Appl. Phys. Lett., Vol. 4, pp. 93-94(L), Mar. 1, 1964

Experimental evidence that SnTe is a semiconductor is presented. The samples were prepared at pressures of about 15 kbar, with either polycrystalline SnTe containing about 50.4 at.% Te or a stoichiometric two-phase mixture as the starting material. All the high pressure samples had p^*_{300} (apparent carrier concentration) values between 3.6×10^{19} and 7.3×10^{19} cm^{-3}. The increase in Hall mobility with decreasing p* observed in the high-pressure samples is consistent with two different proposed energy band models which classify SnTe as either a semiconductor with two valence bands, or a semimetal. The experimental results for the variation of thermoelectric power at 300°K with p^*_{300} and the change in Hall coefficient of SnTe samples between 77° and 300°K are explained by the two-valence-band model.

23,834 SOME EXPERIMENTAL DATA ON THE SEMICONDUCTION PROPERTIES OF INDIUM SULPHIDE CRYSTALS by M.H. Checinska (Tech. U. Warsaw); Acta Phys. Polonica, Vol. 24, pp. 451-463, Oct. 1963

Indium trisulphide was synthesized in a two zone furnace under sulphur pressure. Crystals were selected by using polarization or phse-contrast microscopes. A number of monocrystals and polycrystalline plates were provided with electrodes to measure the photoconductivity, conductivity and thermoelectric power. These exhibited high photoconductivity in the visible region. For determining the refractive index, the "real over apparent depth" method was used. The dielectric constant of the crystal at radio frequencies was measured. Infrared emission was also investigated.

23,835 NEW SEMICONDUCTING ARSENO PYRITE-TYPE COMPOUNDS by F. Hulliger (Cyanamid European); Nature, Vol. 201, pp. 381-382, Jan. 25, 1964

Discovery of fourteen new ternary semiconducting arsenopyrite type compounds of Ru and Os with group VB and group VIB elements and measurement of their thermoelectric power, electrical resistivity and/or diffuse reflectance are reported. All of the above compounds tested magnetically revealed a weak, almost temperature independent diamagnetism. The possibility of the existence of RuBiSe and/or RuBiTe is mentioned, despite failure to synthesize it during the current study. Data on lattice constants, monoclinic angle, thermal or optical energy gap, diamagnetic susceptibility at room and liquid nitrogen temperatures for these compounds are furnished.

Text on Rhenium - See 23,516

Applications of:
- B - See 23,517
- SiC - See 23,518

Data Sheets on ZnS - See 23,519

CRYSTAL PHYSICS

Covalency Parameters of $CrCl_3$ - See 23,579

ENERGY BAND STRUCTURE

23,836 APPLICATION OF THE MODIFIED AUGMENTED PLANE WAVE METHOD TO COPPER by H. Bross and H-G. Junginger (Tech. Hochsch. Stuttgart); Phys. Lett., Neth., Vol. 8, pp. 240-241(L), Feb. 15, 1964

The calculation of the band structure of copper by the modified augmented plane wave method is discussed. A muffin-tin potential, which simplifies the calculations and is spherically symmetric within the sphere touching the Wigner-Seitz cell and constant in the remainder of the cell, was used. The energy versus $\vec{k}$, $E(\vec{k})$, was computed along the 100, 110, and 111 axes of $\vec{k}$ space for the six bands due to the 3d- and 4s-electrons.

23,837 ENERGY BANDS FOR SOLID ARGON by L.F. Mattheiss (MIT); Phys. Rev., Vol. 133A, pp. A1399-1403, Mar. 2, 1964

Energy bands have been calculated for solid argon using the augmented plane-wave method. The crystal potential used in this calculation has been approximated by a superposition of atomic potentials and involves the Slater-free-electron exchange approximation. In order to estimate the error introduced by this approximation, a quantitative comparison has been made between the Hartree-Fock and free-electron exchange potentials for atomic argon. The results indicate that the free-electron exchange approximation is most accurate for the less tightly bound valence electrons, though errors of the order of 0.1 Ry remain. The present energy bands are found to be in qualitative agreement with the earlier results of Knox and Bassani, though there are important quantitative differences. The present calculation yields a band gap of 13.3 ev, which is in fair agreement with the experimentally observed value of 14.3 ev.

23,838 BAND STRUCTURE OF PbS by E.D. Palik and D.L. Mitchell (U.S. Naval Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 292(A), Mar. 1964

By a combination of interband and free-carrier experiments performed on epitaxial and natural crystals, the energy-band parameters of PbS in the vicinity of the band edge have been determined. Interband magneto-optical-absorption measurements at 77°K establish that the valence and conduction bands are nondegenerate (except for spin), approximately spherical and parabolic, and have extrema at the same point in k space. Measurement of the Burstein effect in the 0-field absorption edge indicates that the bands lie at the <111>-zone boundaries. The energy gaps and reduced effective masses are (0.310 ± 0.01) ev and $(0.055 \pm 0.003)m_0$ for a natural crystal and (0.279 ± 0.002) ev and $(0.051 \pm 0.003)m_0$ for epitaxial crystals on a NaCl substrate. The g factors were also determined. The epitaxial crystals were unavoidably strained due to differential thermal expansion of film and substrate. Values of $(0.12 \pm 0.01)m_0$ for both the valence and conduction effective masses were obtained from free-carrier Faraday-rotation measurements on p- and n-type samples at a temperature slightly above 77°K. Additional structure was observed in the p-type rotation measurements, indicating possible intervalence-band transitions.

23,839 ENERGY BAND STRUCTURE OF NICKEL by M. Fukuchi, J. Yamashita and S. Wakoh (NTT); Rev. Electr. Commun. Lab. NTT, Vol. 12, pp. 161-173, Mar.-Apr. 1964

The energy band structure of Ni is investigated by the modified tight binding approximation and the Green's function method. Proper l-dependent potentials are used for computation. The general character of the 3d-bands is quite similar to that in Cu. The total width of the 3d-bands is estimated as 0.304 ry by TBA, and 0.314 ry by GFM.

23,840 LOW TEMPERATURE PIEZORESISTANCE IN N-GERMANIUM by M. Nakamura and W. Sasaki (Electrotech. Lab., Tokyo); J. Phys. Soc. Japan, Vol. 19, p. 236(L), Feb. 1964

The piezoresistance of n-type Ge doped with $< 10^{18}$ cm^{-3} Sb or As atoms and its energy band structure are described. The impurity band is separated from the conduction band and the mobility of electrons in the impurity band is lower than in the conduction band. The impurity band consists of 4 sub-bands corresponding to 4 valleys of the conduction band. Evidence is presented to show that the impurity band is rigid with fixed parameters such as effective mass and mobility anisotropy independent of excess donor concentration.

23,841 INTERBAND EXCITON AND SCATTERING STRUCTURE IN THE ULTRAVIOLET SPECTRA OF ALKALI HALIDES AND SOLID RARE GASES by J.C. Phillips (U. Chicago); Phys. Rev. Lett., Vol. 12, pp. 142-145(L), Feb. 10, 1964

The ultraviolet spectra of the alkali halides and solid rare gases are analyzed. The energy band structure of these crystals has been determined over a range of 15 ev. The energy band structure of KI is shown, and important transitions for KI and KBr are tabulated. These energy bands explain the plateau observed in the photoemission of the alkali halides above threshold. The "extra" excitons in the exciton spectra have been identified as metastable excitons, the characteristic properties of which are discussed.

Energy Band Structure of:
GaSb - See 23,977
PbS - See 24,040
SnTe - See 23,833
AuSi - See 24,069
TiC_xN_{1-x} and $TiV_{1-x}C$ - See 24,055

23,842 FORBIDDEN BANDWIDTH AND EFFECTIVE CHARGE OF IONS IN THE CRYSTAL LATTICE OF ZnS by M.V. Fok; Soviet Phys.-Solid State, Vol. 5, pp. 1085-1088, Dec. 1963

The difference between the optical and thermal values of the forbidden bandwidth in ZnS is discussed. Two independent methods are used to estimate this difference. From the value of this difference, and from the magnitudes of the longitudinal and transverse optical phonons and the static and dynamic dielectric constants, the effective ion charge was determined and was found to be half of the electron charge.

23,843 CONCERNING CERTAIN PROPERTIES OF NARROW BAND GAP SEMICONDUCTORS by V.L. Bonch-Bruevich (Lomonosov Moscow State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1984-1985(L), Mar. 1964

The probability of transitions across a narrow band gap due to an electron-phonon interaction is calculated. The phonon induced recombination properties are discussed briefly. It is found by a rough estimate that the carrier lifetime at 4°K can range from 10^{-4} to 10^{-13} sec depending on the doping of the specimen.

Energy Gap of:
InSb - See 24,053
Superconducting Nb - See 24,030
Superconducting Films - See 24,015

23,844 HALL EFFECT INVESTIGATION ON LITHIUM-DIFFUSION GALLIUM ARSENIDE by C.S. Fuller and H.W. Allison (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 1227-1232, Apr. 1964

Hall effect results on GaAs crystals into which Li is introduced at 500°C, as well as at higher temperatures, and subsequently removed in Ga or in air at 100°C are reported. Four acceptor ionization energies: 0.023 and 0.11 ev (previously reported), 0.05 ev and 0.14 ev are found. The two levels 0.023 and 0.05 ev are attributed to Li self-pairs. The 0.11- and 0.14-ev levels are associated with Cu possibly already present in the GaAs crystals. The 0.023-ev level is found in crystals produced by the floating-zone process at all temperatures of the Li diffusion. The 0.023-ev level is also found in the horizontal Bridgman crystals when diffusion is above ~650°C. Below ~500°C, however, the 0.05-ev level predominates in Bridgman crystals and the 0.023-ev level is not observed. The origins of the various levels are discussed.

Energy Levels in Si - See 23,974

23,845 ON THE DENSITY OF ELECTRON STATES IN THE CONDUCTION BAND OF BISMUTH by D.V. Gitsu and G.A. Ivanov (Gertsen State Pedagogical Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1023-1025, Nov. 1963

The density of electron states in the conduction band of bismuth is calculated on the basis of the ellipsoidal model. It is shown that when the chemical potential level is displaced from 0 to 0.4 ev, the density of states is still satisfactorily described by the law that it is proportional to the square root of the energy.

Valence Band in ZnSb - See 24,329

23,846 THE FERMI SURFACE OF BERYLLIUM by J.H. Terrell (Brandeis U. and MIT); Phys. Lett., Neth., Vol. 8, pp. 149-151(L), Feb. 1, 1964

An energy band calculation of hcp beryllium by the augmented plane wave method is discussed. Energy eigenvalues have been determined at forty-five points in $1/24^{th}$ of the first Brillouin zone along the major symmetry direction and at points of lower symmetry in the planes ΓKM, ΔUP, and ALH. Calculations made at 1152 points over the entire zone yielded a Fermi energy $E_F = 0.84 \pm 0.01$ Ry from the bottom of the band. The Fermi surface consists of a hole region in the form of a six cornered coronet connected by tiny necks, and an electron region in the form of two cigars, each of which has a slight indentation in the midsection, which is triangular and becomes circular towards the ends. The theoretical Fermi surface determined by the augmented plane wave method is in good agreement with that determined by Watts from deHaas-van Alphen measurements, and also with the Fermi surface calculated by the orthogonalized plane wave method.

23,847 STUDY OF THE SHUBNIKOV-DEHAAS EFFECT. DETERMINATION OF THE FERMI SURFACES IN GRAPHITE by D.E. Soule, J.W. McClure and L.B. Smith (Union Carbide); Phys. Rev., Vol. 134(A), pp. A453-470, Apr. 20, 1964

Measurements of the oscillatory magnetoresistance of a high-quality graphite single crystal are reported. The results were analyzed by a least-squares fitting to a generalized Landau formula. Oscillations due to electrons were observed for all orientations (including $\vec{H} \perp c$, where the amplitude dropped by a factor 10^5), proving that the electron Fermi surfaces are closed. Although oscillations due to holes were not observed beyond $\theta \simeq 84°$, indirect arguments show that the hole Fermi surfaces are also closed. Both electron and hole surfaces are elongated along the c axis and have anisotropy ratios of 12.1 ± 1.4 and about 17, respectively. The electron surface is approximately ellipsoidal, whereas the hole surface is similar except for extended ends giving it a diamond-like shape. The results are consistent with a moderate degree of trigonal asymmetry about the c axis. Comparison between the electron density found from the volume of the electron Fermi surfaces and that determined previously from the nonoscillatory galvanomagnetic data confirms the theoretical prediction that there are four electron Fermi surfaces in the Brillouin zone. More indirect arguments show that there are two hole surfaces. Analysis of the temperature and magnetic field dependence of the oscillatory amplitude yields effective mass values in the basal plane of $(0.039 \pm 0.001)m_0$ for electrons and $(0.057 \pm 0.002)m_0$ for holes. The large amplitude and asymmetric shape of the oscillations in the magnetoconductivity, measured for $\vec{H} \parallel c$ at 1.26 and 4.22°K, are accurately described by the theory of Adams and Holstein. The effective change in temperature due to collision broadening ΔT is about 5 times greater than that estimated from the conductivity relaxation time.

23,848 FERMI SURFACE OF LITHIUM BY POSITRON ANNIHILATION by A. T. Stewart, J.J. Donaghy, J.H. Kusmiss and D.M. Rockmore (U. North Carolina); Bull. Am. Phys. Soc., Vol. 9, p. 238(A), Mar. 1964

The momentum distribution of annihilation photons has been measured for positrons annihilating in single crystals of lithium. The crystals were oriented in the (100) and (1$\bar{1}$0) directions, and the data are assumed to yield the areas of slices through the Fermi surface perpendicular to these directions. The data show clearly that the Fermi surface of lithium is anisotropic. A preliminary analysis of the data has been made, using as a model of the Fermi surface a sphere distorted by an amount $\Delta k = A \exp(-a\theta^2)$, where θ is the angular distance from the nearest (110) direction. The parameter a was arbitrarily taken to be 9 rad^{-2}. Using this model, a fair fit to present data was obtained with A approximately 5 per cent of the free electron radius. The model then prescribes that $k_{100} \approx k_{111} \approx 0.98k_{free}$ and $k_{110} \approx 1.03k_{free}$.

23,849 POSITRON ANNIHILATION IN RARE-EARTH METALS by D.R. Gustafson and A.R. Mackintosh (Iowa State U.); J. Phys. Chem. Solids, Vol. 25, pp. 389-394, Apr. 1964

The electronic structure of three rare-earth metals has been studied by measuring the angular correlations of the photons emitted when positrons annihilate with the electrons in the metal. From the results it is deduced that gadolinium and cerium at room temperature each has approximately three conduction electrons per atom, while ytterbium has approximately two as expected from the localized f-electron model. Qualitative information is obtained about the distortion of the Fermi surfaces of these three metals and it is concluded that the

polarization of the conduction electrons in the magnetically ordered state of gadolinium is small. Annihilations with ion core electrons comprise a significant proportion of the total in each metal, the number relative to the conduction electron annihilations decreasing with increasing atomic number.

23,850 POSITRON ANNIHILATION IN SODIUM SINGLE CRYSTALS by J.J. Donaghy and A.T. Stewart (U. North Carolina); Bull. Am. Phys. Soc., Vol.9, p. 238(A), Mar. 1964

The momentum distribution of annihilation photons has been measured for positrons annihilating in single crystals of sodium. Assuming that these data yield areas of slices through the Fermi surface perpendicular to the selected (100) and (110) directions, the results indicate that: (a) the number of free electrons is 1.02 ± 0.03 per atom; (b) the annihilation probability is velocity-dependent. Kahana's calculation fits the data reasonably well, using r_s as a phenomenological parameter with a value of about 5 a.u. instead of 3.9 a.u., which is the value for sodium; and (c) the Fermi surface of sodium appears spherical to present experimental accuracy.

23,851 FERMI SURFACE OF SODIUM FROM STUDY OF HELICON WAVES by M.T. Taylor (Cornell U.); Bull. Am. Phys. Soc., Vol. 9, p. 238(A), Mar. 1964

It is possible to determine the radius of the Fermi surface from a study of helicon waves when the electron mean free path is very much longer than the helicon wavelength. Experiments have been carried out on standing waves in thin plates (down to 45 μ thick) and also on waves propagating through thick plates (~1 mm thick). All the measurements were made on polycrystalline sodium with a residual-resistance ratio of 7500. The radius of the Fermi surface is deduced from a study of the dispersion relation and the damping of the waves. The value of the radius of the Fermi surface of sodium was found to be very close to 0.92×10^8 cm^{-1}, the value expected for a spherical energy surface.

23,852 FERMI SURFACE OF CALCIUM BY THE DE HAAS-VAN ALPHEN EFFECT by J.H. Condon (Natl. Sci. Found.) and J.A. Marcus (Northwestern U.); Phys. Rev., Vol. 134A, pp. A446-452, Apr. 20, 1964

The de Haas-van Alphen effect of calcium has been studied by the torsion method in fields to 33 kg. The three periodicities of 3.05, 0.77, and 0.57 (10^{-7}G^{-1}) that were observed had cyclotron masses of 0.3_5, 0.6_5, and $0.6_5 m_0$, respectively, and imply areas of orbits that are in agreement with a Few-OPW model with small lattice potentials, $V_{200} = 0.34_5$ Ry and $V_{111} = 0.01_4$ Ry. The experimentally-determined cyclotron masses are nearly twice those given by the model.

23,853 INVESTIGATION OF THE FERMI SURFACE IN LEAD BY THE CYCLOTRON RESONANCE METHOD by R.T. Mina and M.S. Khaikin (Acad. Sci. USSR); Soviet Phys.-JETP, Vol. 18, pp. 896-905, Apr. 1964

Measurement of the effective masses of carriers in lead in the two principal crystallographic planes is reported. The results are discussed and compared with the model of the Fermi surface set up in the nearly free electron approximation. The characteristic features of the surfaces of the second and third zones are found to be in qualitative agreement with the experimental results. The principal dimensions of the surface of the third zone are determined, and minor differences between the zone and the model are noted. It is shown from the results that the fourth zone is vacant.

23,854 FERMI SURFACE OF W AND Mo by D.M. Sparlin and J.A. Marcus (Northwestern U.); Bull. Am. Phys. Soc., Vol. 9, p. 250(A), Mar. 1964

An approximation to the Fermi surface for tungsten and molybdenum was constructed from the results of dHvA measurements fitted to the topology predicted by band calculations. The surface so derived is shown to be compatible with the results of other types of measurements. The electron surface centered on is similar to a child's jack and a sphere formed on the end of each of the six arms. The hole surface centered on H is also "jacklike" but with smoothly tapered arms. There are generalized hole ellipsoids at N with major axes along <100> in both metals, Mo having the larger volume of these carriers. The electron pockets formed by Δ_2 and $\Delta_{2'}$ along ΓH are "lens"-shaped and seem to exist only in Mo. The lower branch at the intersection of Δ_2 and $\Delta_{2'}$ supports a "neck" orbit on the arm of the electron "jack" that was observed in both metals.

Fermi Surface of:
Mo and W - See 24,227
Re - See 24,315

23,855 ENERGY STATES AT THE INTERFACE OF TWO SEMI-INFINITE ONE-DIMENSIONAL CRYSTALS by S.K. Ghosh and A.K. Laskar (Indian Inst.Tech., Kharagpur); Indian J. Phys., Vol. 37, pp. 534-539, Oct. 1963

Localized energy levels at the interface of two similar semi-infinite crystals with adsorbed gas at the interface are computer by the scattering matrix method. The calculations have been made first for a clean interface and then for an impurity atom at the interface. The results show the existence of localized states at a certain potential strength of the adsorbed gas. Some experimental evidence for the theoretical results are given.

23,856 SURFACE STATES IN III-V COMPOUNDS by P. Phariseau (Lab. Kristalkunde, Gent); Physica, Vol. 30, pp. 608-614, Mar. 1964

The energy spectrum of an electron moving in a semi-infinite one-dimensional model of a III-V compound is described by means of a Green's function method in the one electron approximation. The transcendental equation giving the energy of the surface states are discussed numerically for a few characteristic values of the parameters. The surface-states seem to be strongly dependent on what kind of bond is broken at the surface.

23,857 SURFACE STATES ON (111) SURFACES IN GaAs by G. Rupprecht and J.F. Gilbert (Tyco Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 258(A), Mar. 1964

Surface states on (111) A and B surfaces of GaAs were examined by means of the pulsed-field effect. With zinc-doped P-type GaAs, a surface state was found on the B surface 0.53 ev above the valence band with a capture cross section for holes of about 10^{-12} cm^2, which is indicative of an acceptor state. With "undoped" N-type GaAs, two surface states were observed simultaneously on the B surface: $E_1 = 0.56$ ev below the conduction band with a capture cross section of the order of $\sigma_1 \approx 10^{-12}$ cm^2 and $E_2 = 0.3$ ev below the conduction band with a capture cross section for electrons of the order $\sigma_2 \approx 10^{-22}$ cm^2. Level E_1 is identified as a donor state, whereas E_2 appears to be an acceptor state. On the A face of this sample, a spectrum of surface states was observed in the range between 0.2 and 0.5 ev below the conduction band.

23,858 STUDY OF SURFACE STATES IN SEMICONDUCTORS by G. Rupprecht (Tyco Labs.); Dec. 1963, 17 pp., Contract AF30 602 3157, Proj. 5519; U.S. Gov. Res. Rep., Vol. 39, p. 14(A), Apr. 5, 1964 AD 427 117 OTS $2.60

Pulsed field effect measurements of the surface states of Ge and Si are described. Measurements on n-type Si indicate surface states with cross-sections of 10^{-12} cm^2, 0.73 ev below the conduction band, near those previously reported at 0.62 ev. The pulsed field effect experiment on Ge surfaces, however, revealed slow surface states whose decay times increased as adsorbed gases were removed.

LATTICE VIBRATIONS

23,859 INTERPRETATION OF ELECTRONIC-VIBRATIONAL TRANSITIONS IN IMPURITIES ON THE BASIS OF A DYNAMICAL THEORY OF NONIDEAL LATTICES by N.N. Kristofel and G.S. Zavt; Optics and Spectrosc., Vol.16, pp. 140-142, Feb. 1964

The change in crystalline vibrations in the region of lattice defects has been investigated. It has been shown that the displacements of the atoms nearest to the defect can have sharp maxima as a function of frequency in a number of cases. The frequencies at which the maxima occur either determine the effective frequencies of the impurity center or manifest themselves as narrow quasi-lines (in centers with large or small Stokes losses, respectively). A corresponding analysis of experimental and theoretical results for various luminescence centers is also given.

23,860 LOCALIZED VIBRATION MODES IN CUBIC CRYSTALS WITH POINT DEFECTS [in German] by K. Dettmann and W. Ludwig (Tech. Hoch., Aachen); Phys. of Cond. Matter, Vol. 2, pp. 241-261, Apr. 1964

The localized modes of vibration are discussed for a face centered and a body centered cubic lattice, if the ideal crystal is perturbated by a substitutional impurity. The eigenvectors are found by group-theoretical considerations; the frequencies can be calculated approximately by a variational principle, which gives good results if the mode is strongly localized. The changes in mass and coupling parameters which can give rise to localized modes of vibration are described. It turns out that in the model considered (nearest neighbor interaction and no changes in lattice structure), a vacancy does not show localized vibrations.

23,861 WHY HAVE THE VIBRATIONAL FREQUENCY SPECTRA OF DISORDERED CHAINS MANY DISTINCT PEAKS? by J.Hori and M. Fukushima (Hokkaido U.); J. Phys. Soc. Japan, Vol. 19, pp. 296-307, Mar. 1964

By using a vector picture introduced previously, it is shown that disordered diatomic chains with sufficiently large mass-ratio have very strong tendency to have eigenfrequencies which are close to those of localized modes produced by several types of islands containing light atoms imbedded in a regular lattice composed of heavy atoms. This explains why the vibrational frequency spectra of disordered chains have in general very complicated structures with many well-defined peaks.

Helicon-Phonon Interactions in Metals - See 24,231

Phonon Attenuation in Nb - See 24,030

23,862 DEPENDENCE OF THE FREQUENCY SPECTRUM OF THE SIMPLE CUBIC LATTICE ON DEFORMATION by A.I. Gubanov and A.A. Nran'yan (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1220-1222, Dec. 1963

The change in the vibration spectrum of a simple cubic lattice under the influence of a small tensile deformation is calculated. It is shown that the well-known Grüneisen approximation is not valid and in the second nearest neighbor approximation, the maximum of the frequency distribution curve is lowered and shifted toward lower frequencies for deformed lattices.

23,863 DYNAMICS OF ZnS-TYPE CRYSTAL LATTICES HAVING IONS WITH VARIABLE FRACTIONAL CHARGES by E.N. Korol' and K.B. Tolpygo (Shevchenko Kiev State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1597-1606, Feb. 1964

The expression for the ion-ion interaction potential and the equations for the vibrations of a ZnS type lattice are derived on the assumption that at equilibrium the valence electrons are distributed between the atoms in such a way that each atom has a fractional mean charge. Each pair of electrons binding two nearest atoms has a certain probability of belonging to each of the atoms or forming a σ-bond. The probabilities will change when the nuclei are displaced or when an electric field is acting, and this produces a change in the mean atomic charges.

23,864 ON THE LATTICE VIBRATION OF CUBIC $BaTiO_3$ by W. Kinase, K. Matuura (Waseda U.) and Y. Ishibashi (Tokyo U.); J. Phys. Soc. Japan, Vol. 19, pp. 264-268, Mar. 1964

Numerical calculations are made on the lattice vibration of cubic $BaTiO_3$, the interactions among the constituent ions being taken into account. With some "enhancement factors" introduced for the dipole interaction, which have hitherto been overlooked, the reciprocity law is made consistent with regard to the respective interactions among the ions. It is found that, among the three modes which are optically active, the lowest mode is the bending type and becomes rapidly unstable for the increasing dipole interaction.

23,865 OPTICALLY ACTIVE LATTICE VIBRATIONS OF ZINC BLENDE TYPE AND WURTZITE TYPE CRYSTALS by M. Tsuboi (U. Tokyo); J. Chem. Phys., Vol. 40, pp. 1326-1336, Mar. 1, 1964

Normal coordinate treatment has been made of the optically active lattice vibrations of zincblende-type and wurtzite-type crystals. Based upon the results of this treatment and upon the observed lattice frequencies, discussions are given on the force constants of cubic and hexagonal silicon carbides, zincblende, wurtzite, and a few other crystals having the same type of crystal structure as either one of the above two. The hydrogen-bond stretching force constant in hexagonal ice whose crystal structure is similar to that of wurtzite has been estimated to be 0.18 mdyn/A.

23,866 CHARACTERISTICS OF THE THERMAL VIBRATION SPECTRUM by V. T. Borisov, E.Z. Vintaikin and L.P. Potapov (Bardin Central Sci. Res. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1848-1852, Mar. 1964

A method for determining the moments of the frequency distribution function from the heat capacity and the thermal X-ray scattering factor is described. The method has been used to calculate the moments of the frequency distribution function from ω^{-25} to ω^{4} for silver and lead, and to calculate the deviations of the moments from the Debye values. It is shown that the departure from the Debye moments is insignificant for silver and lead, and it is suggested that the Debye temperature for monatomic cubic lattices is a very accurate measure of the binding forces.

23,867 DETERMINATION OF THE PHONON SPECTRUM FROM THE CROSS SECTION OF INCOHERENT SCATTERING OF NEUTRONS IN A CRYSTAL by B.D. Laikhtman (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2222-2223(L), Apr. 1964

It is shown that if the interaction of neutrons with any number of phonons is taken into account, the phonon distribution function may be fully constructed from the cross section of the incoherent scattering in one specimen. The formula for the phonon distribution function is derived.

23,868 PHONON SCATTERING IN SEMICONDUCTORS FROM THERMAL CONDUCTIVITY STUDIES by M.G. Holland (Raytheon); Phys. Rev., Vol. 134A, pp. A471-480, Apr. 20, 1964

The lattice thermal conductivity of a number of semiconductors including InSb, GaAs, GaSb, CdTe, and CdS has been measured between 1.7 and 300°K. This, together with previous work on Si and Ge, is used to investigate the validity of the relaxation time expressions for scattering of phonons by boundaries, atomic impurities and electrons, and to discuss phonon-phonon interactions and resonance scattering effects. The results indicate that the boundary scattering and isotope scattering relaxation times lead to accurate calculated values of thermal conductivity only when the materials are exceptionally pure. Structure, which has been identified as due to resonance scattering, has been observed in the data for most of the materials. Electron-phonon scattering has been noted in GaSb but the complexity of the problems make the analysis only qualitative. The maximum transverse acoustical phonon frequency may be of more significance than the Debye temperature for thermal conductivity calculations.

23,869 PHONON MEAN FREE PATH IN SILICON BETWEEN 77 AND 250°K by R. Gereth and K. Hubner (Shockley Res. Lab.); Phys. Rev., Vol. 134A, pp. A235-246, Apr. 6, 1964

Measurement of transmitted phonon drag across 10 ohm cm p-type silicon indicates a phonon mean free path of the relevant thermal phonons which varies from about 80 μ at 77°K to 12 μ at 250°K. The values depend on the method of evaluation. A simplified analysis suggests that below 150°K the longitudinal acoustic branch of the phonon spectrum is dominant.

ELECTRONIC STRUCTURE

23,870 A NEW METHOD FOR THE ELECTRONIC STRUCTURE OF METALS by V. Heine and I. Abarenkov (Cavendish Lab.); Phil. Mag., Vol. 9, pp. 451-465, Mar. 1964

A new method is described for setting up the effective potential for electrons in nontransition metals, including liquid metals and alloys. It is based on a model potential fitted to the spectroscopically measured energy levels of the free ion. The potential between the atomic cores is obtained from the dielectric screening calculation of Cohen and Phillips with some refinements. The method is tested on the band structures of the (solid) alkali metals. The Fermi surfaces of K, Rb and Cs are found to be considerably less distorted than calculated by Ham, and thus in better agreement with experiment.

23,871 POSITRON ANNIHILATION IN ALKALI HALIDES by A. Bisi, A. Fiorentini and L. Zappa (Phys. Inst., Milan); Phys. Rev., Vol. 134A, pp. A328-331, Apr. 20, 1964

The time annihilation spectrum of positrons in most alkali halides is measured. Positrons appear to decay through at least two different processes which lead to a complex time annihilation spectrum. The first component is conceivably due to positrons which annihilate when free; the second, which occurs with an intensity I_2 between 25 and 85 per cent, is characterized by a mean life τ_2 whose amount ranges between 4×10^{-10} and 8×10^{-10} sec. From the whole set of the collected data, empirical regularities can be extracted; the annihilation rate λ_2 appears simply correlated with the molecular density n within each halide series, according to the relation: $\lambda_2 = \lambda_0 + an$. λ_0 decreases, passing from fluorides to bromides, and a turns out to be simply proportional to the square of the radius of negative ion. The τ_2 component is sensitive to the application of a static magnetic field; the magnetic quenching, however, is appreciably lower than what would be expected if one attributes this component to the decay of a free positronium atom.

23,872 ELECTRONIC g FACTORS OF THE p^2 CONFIGURATION IN GeI AND SnI by W.J. Childs and L.S. Goodman (Argonne Lab.); Phys. Rev., Vol. 134A, pp. A66-69, Apr. 6, 1964

Electronic g factors have been obtained by the atomic-beam magnetic-resonance technique for all $J \neq 0$ states arising from the p^2 electronic configuration in GeI and SnI. The results for the $^1D_2$, $^3P_2$, and $^3P_1$ states for Ge are 1.00639(8), 1.49458(9), 1.50111(7); and for Sn they are 1.05230(8), 1.44878(9), and 1.50110(7); respectively. The results are compared with intermediate-coupling calculations.

ELECTRICAL PROPERTIES

NUCLEAR QUADRUPOLE EFFECTS

23,873 A METHOD OF MEASURING NUCLEAR QUADRUPOLE RESONANCE SPECTRA AT LOW TEMPERATURES by V. Babenko and D. Baisa (Acad. Sci. USSR); Cryogenics, Vol. 4, pp. 40-41(L), Feb. 1964

The design of a metal cryostat for the measurement of nuclear quadrupole resonance spectra at liquid helium and hydrogen temperatures is described. Precaution is taken so that the components surrounding the coil of the tank circuit do not have any significant effect on the operational parameters. One disadvantage of the design is that the specimen, once immersed in liquid helium, cannot be changed when the cryostat is cold.

3,874 NUCLEAR QUADRUPOLE INTERACTIONS IN BERYLLIUM OXIDE by .T. Taylor and T.P. Das (U. California, Riverside); Phys. Rev., Vol. 133A, p. A1327-1333, Mar. 2, 1964

he importance of the contribution from higher multipole moments of oxygen ons to the electric field gradient at nuclei in a wurtzite-type ionic oxide, amely, beryllium oxide, is considered and, in particular, oxygen dipole mo- ents are found to contribute significantly to the field gradient at beryllium on sites. The dipolar polarizability of an oxygen ion bound in a beryllium ox- de lattice is analyzed and a value of 2.19 A^3 is obtained. Using 7.0 A^5 for the uadrupolar polarizability of the same ion and considering the slight uncertain- y associated with the sublattice displacement parameter u, the experimental uadrupole coupling constant for the Be^9 nuclei, $\pm 41 \pm 4$ kc/sec, can be ex- lained. The quadrupole coupling constant for O^{17} nuclei is also investigated nd presented as a function of u. In this case, oxygen dipole moments do not ontribute because of lattice symmetry; oxygen quadrupole moments do contri- ute, however.

3,875 ELECTRICAL QUADRUPOLE INTERACTIONS IN RARE EARTH IONS y A.J. Freeman and R.E. Watson (MIT Magnet Lab.); DA Proj. 1H024401A-10, Dec. 1963, 10 pp.; U.S. Gov. Res. Rep., Vol. 39, p. 134(A), Apr. 20, 964 AD 429 189 OTS $1.60

Quadrupole interactions in rare earth ions arising from electric field gradients ue to valence electrons (q_{4f}) and/or crystal fields external to the ion (q_{lat}) re discussed. Sternheimer antishielding contributions to q_{4f} and q_{lat} are cal- ulated for the Ce^{3+} ion using a method based on the unrestricted Hartree-ock formalism. The ionic antishielding factor is -73.5 and the total ionic con- ribution to the electric field gradient is found to be comparable in magnitude and maybe opposite in sign) with the valence electron contribution (augment- d by the internal antishielding factor).

3,876 QUADRUPOLE COUPLING CONSTANT, eqQ/h, OF Fe^{3+} IN SEV- RAL RARE-EARTH IRON GARNETS by W.J. Nicholson and G. Burns (IBM Watson Lab.); Phys. Rev., Vol. 133A, pp. A1568-1570, Mar. 16, 1964

Using the Mössbauer effect, values of eqQ/h of Fe^{3+} have been obtained at each of two sites in several rare-earth iron garnets. The measured values of eqQ/h were compared with values obtained using a point-charge lattice sum alculation. For the octahedral (a) site there was reasonable agreement be- ween the measured and calculated values of eqQ/h indicating that an ionic odel is reasonably valid. However, the measured values of eqQ/h at tetra- edral (d) sites were larger than those estimated. This difference is attributed o a small amount of covalent bonding which is also evident in the values of he (d) site internal field and isomer shift.

3,877 Al^{27} QUADRUPOLE COUPLING IN SOLID $AlCl_3$ by P.A. Casabella nd N.C. Miller (Rensselaer Polytech.); J. Chem. Phys., Vol. 40, pp. 1363-368, Mar. 1, 1964

The nuclear quadrupole coupling constant of Al^{27} in solid anhydrous $AlCl_3$ was ound to be 472 ± 24 kc/sec with an electric field gradient asymmetry param- ter of zero. Assuming the crystal to be completely ionic, the electric field radient was calculated for the layered $AlCl_3$ structure by summing the contri- utions of the near ions, and treating the rest of the crystal as being made up f uniformly charged planes. This calculation gives an Al^{27} quadrupole coupling onstant of -2.78 Mc/sec and an electric field gradient asymmetry parameter f zero. The addition of some covalent bonding tends to reduce the magnitude f the coupling constant and bring it into better agreement with the experimen- al value. It is estimated that the crystal is two-thirds ionic and one-third co- alent.

23,878 NUCLEAR MAGNETIC RESONANCE DETERMINATION OF SOME MICROSCOPIC PARAMETERS OF $LiAl_5O_8$ by G.H. Stauss (U.S. Naval Res. Lab.); J. Chem. Phys., Vol. 40, pp. 1988-1991, Apr. 1, 1964

Quadrupole coupling data have been obtained from analysis of NMR spectra of ^7Li and ^{27}Al in single crystal and polycrystalline ordered $LiAl_5O_8$. On axially symmetric sites, values of $|\nu_Q|$ for ^7Li and ^{27}Al are, respectively, 41 ± 2 kc/sec and 284 ± 6 kc/sec. On ^{27}Al sites with octahedral coordination, $|\nu_Q| = 683 \pm 25$ kc/sec, $\eta = 0.347 \pm 0.025$, and the orientation of principal axes has been found. An ionic model calculation gives estimates of distortions of the crystal from the ideal spinel form and possible signs for the ν_Q values. A convenient general expression for second-order shifts is given, together with results for the positions of the prominent second-order features in the line shapes of poly- crystalline samples.

Nuclear Quadrupole Resonance in $CrCl_3$ - See 23,579

DIELECTRIC PROPERTIES

23,879 TABLES OF DIELECTRIC CONSTANTS, DIPOLE MOMENTS, AND DIELECTRIC RELAXATION TIMES by R.D. Nelson, Jr. (Princeton U.); Natl. Acad. Sci.-Natl. Res. Council Dielectrics Dig. of Lit., Vol. 26, pp. 27-99, 1962-1963; STAR, Vol. 2, p. 727(A), Mar. 23, 1964 AD 424 943

The following tables are given: (1) static dielectric constant of pure liquds; (2) static dielectric constants of pure solids; (3) dipole moments; (4) unresolved relaxation times; (5) resolved relaxation times; (6) extrapolated dielectric constant at infinite frequency for pure liquids; and (7) cross-reference list for dipole type.

23,880 THE DIELECTRIC CONSTANT OF CRYSTALS FROM THE QUANTUM VIEWPOINT by G.M. Grandel'man and V.M. Ermachenko; Soviet Phys.-JETP, Vol. 18, pp. 358-364, Feb. 1964

The integral equation for the inverse dielectric constant operator started by Falk and by Adler is discussed. An expression is obtained for $\epsilon(\omega)$ suitable for the direct calculation of the dependence of $\epsilon(\omega)$ on the density of the medium. Under certain assumptions the behavior of $\epsilon(o)$ during transition to the metallic state is studied, and the singularities in $\epsilon(\omega)$ at the start of the absorption band have been clarified.

23,881 THEORY OF THE DIELECTRIC PERMITTIVITY OF CRYSTALS by V.M. Agranovich and Yu.V. Konobeev; Soviet Phys.-Solid State, Vol. 5, pp. 1858-1865, Mar. 1964

A calculation of the dielectric permittivity tensor of a crystal is carried out in the region of exciton absorption bands by using the method of Green's functions. Neglecting the interaction of excitons with phonons, the expression obtained for the dielectric tensor agrees with the expression obtained by using perturbation theory. It is shown that, taking this interaction into account, it is possible to consider the effect of the long-wavelength edge of the exciton absorption bands.

23,882 THE INFLUENCE OF THE SAMPLE THICKNESS IN THE MEASUREMENTS OF DIELECTRIC CHARACTERISTICS WITH TRANSMISSION LINES BY THE METHOD OF ROBERTS-VON HIPPEL by M. Mandel and C. Marco (U. Brussels); Physica, Vol. 30, pp. 597-607, Mar. 1964

A theoretical expression is derived for the relative error on ϵ' and ϵ'' when measured with the method of Roberts-von Hippel using coaxial transmission lines. This expression is shown to depend on the experimental accuracy of the measureable quantities but also on the characteristic parameters of the sample ϵ', ϵ'' and its thickness h. Numerical calculations show how in various cases these errors change with h. It is also demonstrated that for polar samples the choice of the thickness of the sample may become critical. Some experimental results are given to illustrate this effect.

23,883 DETERMINATION OF THE DIELECTRIC LOSS-ANGLE TANGENT OF DIELECTRICS BY THE RESONANCE CIRCUIT METHOD by P.F. Veselovskii and Yu.D. Suchkov (Kalinin Polytech. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1995-1997(L), Mar. 1964

A simple method for calculating the loss-angle tangent tanδ is proposed. It is shown that if the analytic or experimental form of the dependence of the resonance frequency of the circuit on the permittivity of the test sample is known for a fixed shape of the sample and of the measuring cell, then tanδ may be determined quantitatively for any shape of the sample and the measuring cell.

23,884 METHOD OF MEASURING THE DIELECTRIC CONSTANT AT MICROWAVE FREQUENCIES BY MEANS OF THE PERTURBATION METHOD by I. Falkvik; Proc. IEEE, Vol. 52, p. 203(L), Feb. 1964

The possibility of measuring the dielectric constant and loss of a material at microwave frequencies is discussed. The derived formulas give expressions for the frequency shift and the change of the Q-factor, which are both easily determined by measurements. The shape treated is a sphere, but if rods are used, the formulas are quite similar.

Measurement of Dielectric Constant - See 23,955

23,885 THE MICROWAVE MEASUREMENT OF THE COMPLEX PERMITTIVITY OF SEMICONDUCTORS by M. Gunn (McMasters U., Ontario); Proc. IEEE, Vol. 52, p. 185(L), Feb. 1964

A method of measuring the complex permittivity of semiconductors by the propagation constant (γ_z) of a wave traveling in an inhomogeneously filled waveguide is presented. The sample, a thin rectangular slab, is fitted in the center of a length of waveguide making electrical contact with the walls at top and bottom. Appropriate approximations to the transcendental solution of the H_{10} mode of propagation are given, and a sample calculation is made. The possibility of reflections introduced at the junction of empty and filled waveguides for finite samples can be handled by calculating γ_z from successive measurements, made with the sample cut to different lengths.

23,886 DIELECTRIC PROPERTIES AND PHASES OF SOME Ga_2O_3-Nb_2O_5 CE-

RAMIC COMPOSITIONS by F. A. Philgreen (Sandia); J. Am. Ceramics Soc., Vol. 47, pp. 49-50, Jan. 1964

The dielectric properties of $Ga_2O_3 \cdot Nb_2O_5$, $Ga_2O_3 \cdot 3Nb_2O_5$, $Ga_2O_3 \cdot 4Nb_2O_5$, $Ga_2O_3 \cdot 2Nb_2O_5$, and $2Ga_2O_3 \cdot Nb_2O_5$ have been measured. Curves of dielectric constant versus temperature are presented for each composition. No ferroelectric hysteresis loops were observed. Debye-Scherrer X-ray powder patterns were made for each of the compositions to determine if a separate phase could be identified in the $Ga_2O_3 \cdot 3Nb_2O_5$ ceramic, but no such phase was found. The crystal structure of $GaNbO_4$ was found to be monoclinic. No evidence for the existence of a $GaNb_3O_9$ phase was found.

23,887 DIELECTRIC PROPERTIES AND DC CONDUCTIVITY OF VACUUM-DEPOSITED SiO FILMS by H. Hirose and Y. Wada (U. Tokyo); Japanese J. Appl. Phys., Vol. 3, pp. 179-190, Apr. 1964

The dielectric properties from 10^{-2} to 10^7 c/s and the dc conductivity of vacuum-deposited SiO films have been investigated. The conductivity decreases with increasing oxidation and the activation energy is estimated to be 8.6kcal/mole. Two dielectric dispersions are found, the loss peaks of which are at 10^{-1} c/s (if dispersion) and at above 10^7 c/s (hf dispersion), respectively. The strength of lf dispersion decreases with increasing oxidation and metallic impurities have no appreciable effect on the dispersion. The activation energy of lf dispersion is almost equal to that of dc conduction. The dc conduction and lf dispersion are attributed to diffusion of free Si ions. The hf dispersion is ascribed to local torsional vibration of SiO chains. A model of the molecular structure of SiO in the glassy state is suggested, which is well consistent with the electrical and optical properties of this material.

23,888 DIELECTRIC CONSTANT OF PbTe by N. Watanabe (Sony, Yokohama); Japanese J. Appl. Phys., Vol. 3, p. 166(L), Mar. 1964

A determination of the dielectric constant of PbTe by surface impedance measurements at 24 Gc/sec is reported. Results indicate that κ is probably less than 200. Measurements were made by replacing part of a cavity surface with the sample surface. The differential method was used to measure resonance frequency shifts. The experiment was performed over the 77°-333°K temperature range. The discrepancy between these results and those of Kanai and Shoho ($\kappa \approx 400$) obtained by capacitance measurement of p-n junctions has not been resolved.

23,889 THE VARIATION OF THE DIELECTRIC CONSTANT OF DIAMOND WITH PRESSURE by D.F. Gibbs and G.J. Hill (U. Bristol); Phil. Mag., Vol. 9, pp. 367-375, Mar. 1964

The variation of dielectric constant with pressure of two diamonds has been measured. If an atomic polarizability a is calculated from the Clausius-Mossotti equation, it is found that $V/a(\partial a/\partial V)_T$ has the value 1·2, which conforms closely to its value for silicon and germanium. Some of the results of other workers on the photoelastic properties of diamond are also in conformity with the present results. There is some uncertainty, however, as to the elastic constants of diamond and it seems possible that both these and $V/a(\partial a/\partial V)_T$ may depend significantly on the impurity content of the stones.

Dielectric Constant of Diamond - See 24,322

23,890 DIELECTRIC ANOMALIES ON $NaNO_2$ ABOVE THE FERROELECTRIC CURIE TEMPERATURE by Y. Takagi and K. Gesi (Japan AE Res. Inst.); J. Phys. Soc. Japan, Vol. 19, pp. 142-143(L), Jan. 1964

The dielectric constant and dielectric loss of a (010) plate of $NaNO_2$ have been measured as a function of temperature. Plots of the reciprocal of the dielectric constant versus temperature and tanδ versus temperature are given. On both, appreciable anomalies are shown 1°C above the Curie temperature and are attributed to the antiferroelectric-paraelectric transition.

23,891 APPARENT DIELECTRIC CONSTANT OF RUTILE AT VARIOUS FIELD STRENGTHS by H.B. Lal and Y.D. Singh (U. Allahabad); Phys. Lett., Neth., Vol. 8, p. 165(L), Feb. 1, 1964

Room-temperature measurements of the dielectric constant of rutile parallel and perpendicular to the c-axis as a function of electric field are discussed. The measurements were made at field strengths up to 7.5 v/cm parallel to the c-axis and up to 4.4 v/cm perpendicular to the c-axis. The reed vibrator technique was used to measure the capacity of a rutile condenser. In both cases the dielectric constant was higher than the optical dielectric constant. This increase is associated with trapped electrons which are released from potential wells and mobilized by high fields. At high fields the dielectric constant tends to become constant, either because of the absence of electrons in traps or the inefficiency of the field to free electrons from the traps.

Dielectric Constants of $BaZrO_3$ - See 23,995

23,892 RELAXATION PROPERTIES OF $BaTiO_3$ SINGLE CRYSTALS CONTAINING ANTIMONY AS AN IMPURITY by S.V. Bogdanov, V.A. Rassushin and D.K. Sinkha (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1975-1976(L), Mar. 1964

The temperature dependence of the permittivity of $BaTiO_3$ single crystals with antimony impurity has been investigated in the temperature range 120-200°C. The results show that at certain antimony concentrations $BaTiO_3$ exhibits both ferroelectric and relaxation properties. The introduction of the antimony shifts the Curie point toward lower temperatures. The permittivity above the Curie temperature first decreases with temperature and then rises again. This rise is more marked at lower frequencies.

23,893 MICROCRYSTALLINE $BaTiO_3$ BY CRYSTALLIZATION FROM GLASS by A. Herczog (Corning); J. Am. Ceramic Soc., Vol. 47, pp. 107-115, Mar. 21, 1964

The properties and composition of glasses suitable for crystallization of $BaTiO_3$ are described. The crystallization of certain glasses results in a nearly complete recovery of $BaTiO_3$. The mechanism of crystallization was investigated by thermal analysis, viscosity, and grain size measurements as a function of temperature whereas density data were used for evaluation of $BaTiO_3$ content. Within the range 30-60 volume pct of $BaTiO_3$ (g.s. $\simeq 1\,\mu$), the dielectric constant increased from 100 to 1200. As grain size approached 0.1 μ, the dielectric constant decreased and became nearly independent of temperature. Data are also presented on dielectric constant and loss tangent at different frequencies, dc breakdown strength, dc resistivity, and ferroelectric properties as a function of the grain size of the crystallized material.

23,894 DIELECTRIC CONSTANT OF POWDERS by P. Swarup and R.P. Aro... (Inst. of Armament Studies, Poona); Nature, Vol. 201, p. 1018, Mar. 7, 19...

Dielectric measurements have been made on sulphur powder which is considered to be a mixture of sulphur and air. It was found that K/d was constant with a value of 0.25 where $K = (\epsilon-1)/(\epsilon+2)$ (ϵ = dielectric constant). By comparing the results with those of other investigators, the authors conclude that the K/d ratio is constant for a powder.

23,895 DIELECTRIC DISPERSION IN ROCHELLE SALT by F. Sandy (Harvard U.); Bull. Am. Phys. Soc., Vol. 9, pp. 214-215(A), Mar. 1964

The frequency dispersion of the dielectric constant of Rochelle salt has been measured in the high- and low-temperature nonpolar regions and the intervening ferroelectric region both with and without a dc bias. The dispersion is of relaxation rather than a resonant type, although the form of the relaxation differs from that found by Hall and Ichiki for several other hydrogen-bonded ferroelectrics. The relaxation frequency has minima of about 3 Gc/sec at the Curie points. Above 4.5 Gc/sec, the peaks in the dielectric constant at the Curie points become minima, each surrounded by two maxima that spread apart as the frequency is further increased. Between these maxima, the dielectric constant rises with increasing bias. At other temperatures, it decreases with increasing bias. Increasing the bias also causes the maxima to broaden and merge. The imaginary part of the dielectric constant always peaks at the Curie point and drops with increasing bias.

23,896 MOBILITY OF "SMALL" POLARONS AT LOW TEMPERATURES by I. G. Lang and Yu. A. Firsov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2049-2060, Apr. 1964

The mobility of "small" polarons at low temperatures is determined with the aid of the Kubo formula. Scattering by polarized phonons is assumed to be the fundamental mechanism which limits the mean free path of the current carriers. The limits of applicability of the theory are established, and the question of the role of other scattering mechanisms is discussed.

23,897 FERROELECTRIC TRANSFORMATIONS OF TENSORIAL PROPERTIES IN REGULAR FERROELECTRICS by K. Aizu (Hitachi Res. Lab.); Phys. Rev., Vol. 133A, pp. A1350-1359, Mar. 2, 1964

There are 19 kinds of regular ferroelectrics. Their tensorial properties are changed with their state transition in a manner unique and definite to each of the 19 kinds. A systematic investigation is made into this manner of change. The kinds of tensors examined are the polar and axial tensors of ranks two, three, and four. This theory is expected to serve not only for predicting the manners of change of the tensorial properties in the regular ferroelectrics, but also for determining the kind of a regular ferroelectric crystal and for judging regularity or irregularity of a ferroelectric crystal.

23,898 RADIATION EFFECTS IN FERROELECTRIC MATERIALS by L. Wright, C. Rosen and S. Taimuty (Stanford Res. Inst.); Commun. and Electronics, No. 64, pp. 468-473, Jan. 1963

The effects of reactor radiation [10^{15}-10^{18} neutrons/cm^2] on the dielectric properties of $BaTiO_3$, 96% $BaTiO_3$ + 4% $PbTiO_3$, 95% $BaTiO_3$ + 5% $CaTiO_3$, and lead zircotitanate are reported. Complex permittivity and large-signal hysteresis properties were measured before and after irradiation, after room

mperature aging, and after 500°C heat treatment. Effects on the hysteresis operties and the small-signal permittivity were small except for exposures of om 10^{17} to 10^{18} fast neutrons/cm^2. The Q of all samples was decreased by irdiation, and then increased slowly during room-temperature storage. Heat eatment also decreased the Q of all irradiated samples. The permittivity of e samples receiving 10^{18} neutrons/cm^2 decreased on the average by 30 per nt, while subsequent heat treatment increased the permittivity of all the rium-containing materials.

3,899 ON FERROELECTRICITY AND ANTIFERROELECTRICITY OF THE AO_3-PE CRYSTAL by W. Kinase, Y. Kurasawa (Waseda U.) and Y. Ishibashi (U. kyo); J. Phys. Soc. Japan, Vol. 19, pp. 273-281, Mar. 1964

calculation is performed in order to treat the problem of the relative stabily of ferroelectric and antiferroelectric arrangements of constituent atoms in e AO_3-type crystal such as WO_3, where the electronic polarizabilities of egative and positive ions are regarded as the variable parameters. It is disosed that the stability of each arrangement depends in a delicate manner upn the electronic polarizabilities of the constituent ions, and that, with a reasnable choice of these polarizabilities, the ferroelectricity and antiferroelecicity of tungsten trioxide can be explained. It is also found that a sort of errielectric" state can be realized for some values of the polarizabilities of e ions in the AO_3-type crystal.

3,900 X-RAY AND DIELECTRIC STUDIES OF THE SYSTEMS $(Ba_{1-x}R_{2x/3})Nb_2O_6$, WHERE R IS Y, Sm OR La by K. Masuno (Nippon Tel. and Tel.); Phys. Soc. Japan, Vol. 19, pp. 323-328, Mar. 1964

ew ferroelectric tungsten bronze type solid solutions have been found with mpositions $0.2 \leq x \leq 0.4$ for Sm and La compounds, and $x = 0.25$ for Y comund. The maximum dielectric constants were observed at about $x = 0.2$ for ch system, and corresponding Curie points were 278°C, 189°C and 10°C for , Sm and La compounds respectively. The hysteresis loops were observed bew the respective transition temperatures. In R_2O_3-BaO-Nb_2O_5 system, single ase region of tungsten bronze type structure is determined. The end member the system RNb_3O_9 for Sm, or Y system, was a mixture of $RNbO_4$ and Nb_2O_5, t for the La system a new compound $LaNb_3O_9$ was identified.

3,901 METASTABLE FERROELECTRIC SODIUM NIOBATE by R. Dungan and . Golding (Sandia); J. Am. Ceramic Soc., Vol. 47, pp. 73-76, Feb. 21, 1964

operties of a metastable ferroelectric $NaNbO_3$ phase are described. This ferelectric phase was induced by the application of a field greater than 50 kv r cm at a temperature in excess of 100°C. The ferroelectric state was evienced by a spontaneous polarization of the order of 30 microcoulombs per cm^2 d by fairly strong piezoelectric coupling. The ferroelectric phase, once inuced, was stable with time and temperature up to 270°C.

3,902 DIELECTRIC AND X-RAY STUDIES ON THE FERROELECTRIC PHASE RANSITION OF GLYCINE SILVER NITRATE by S. Mitani (Hokkaido U.); . Phys. Soc. Japan, Vol. 19, pp. 481-486, Apr. 1964

he dielectric constant of GSN measured along the ferroelectric b-axis obeys he Curie-Weiss law with the Curie-Weiss constant of 446°C. Dielectric bevior in the vicinity of the Curie point is well explained by the phenomenogical theory. The coefficient ξ of the P^4 term $(1/4\ \xi\ P^4)$ in the Taylor series xpansion of the elastic Gibbs function has been determined as $\xi = 6.4 \times 10^{-7}$ gs esu by use of the temperature dependence of P_s^2. The lattice deformations ssociated with the spontaneous polarization suggest a strong interaction beween the polarization and the crystal lattice in GSN.

3,903 ON THE FERROELECTRIC-LIKE BEHAVIOR OF LITHIUM HYDRAINIUM SULFATE (LHzS) by N. Niizeki and H. Koizumi (NTT); J. Phys. Soc. apan, Vol. 19, pp. 132-133(L), Jan. 1964

hough ferroelectricity has been reported in $Li(N_2H_5)SO_4$, structural evidence s presented which contradicts the established concept of ferroelectricity. The onding shown by a Fourier map indicates that LHzS either belongs to a new ype of ferroelectric or another origin of dielectric hysteresis must be sought.

3,904 STATISTICAL THEORY FOR FERROELECTRICITY IN TRI-GLYCINE ULFATE by J.A. Gonzalo and J.R. Lopez-Alonso (Puerto Rico Nuc. Ctr.); . Phys. Chem. Solids, Vol. 25, pp. 303-310, Mar. 1964

A study of the behavior of the coercive field and spontaneous polarization of ri-glycine sulfate as a function of temperature is reported. The experimental esults are discussed on the basis of a simple model using classical statistical nechanics. Expressions derived for spontaneous polarization and coercive field re in fair agreement with the experimental plots. A power expansion of the eneral equation obtained by the method employed shows the same behavior as he equivalent equation in Mueller's thermodynamic theory. The transition enropy calculated on the basis of the present model is also reasonably satisfacory.

23,905 PRESSURE DEPENDENCE OF THE FERROELECTRIC PROPERTIES OF ROCHELLE SALT by G.A. Samara (Sandia); Bull. Am. Phys. Soc., Vol. 9, p. 215(A), Mar. 1964

The effects of hydrostatic pressure, up to 20 kbar, on the ferroelectric properties of Rochelle salt, were investigated. With increasing pressure, at room temperature (19°C), the spontaneous polarization P_s first increases, reaches a broad maximum at ~3.5 kbar and decreases to zero by 10 kbar. At the maximum, P_s has a value of 2.3×10^{-7} C/cm^2, or nearly the same as the maximum value obtained at ~5°C at atmospheric pressure, thus indicating no significant changes in the dipole moment and the electronic contribution to the total polarization. In the vicinity of the Curie points, P_s^2 is a linear function of pressure, in agreement with the predictions of the thermodynamic theory. The shifts of the Curie points are in close agreement with Bancroft's results obtained below 10 kbar; however, the shift of the lower Curie point deviates slightly from linearity toward a larger slope at the higher pressures. Above 5 kbar, the upper Curie point occurs above the dissociation temperature. In the paraelectric phases, $1/\epsilon_a$ is, within small ranges, a linear function of both temperature and pressure.

23,906 SOME ASPECTS OF POLARIZATION REVERSAL IN FERROELECTRIC TGS by H.H. Wieder (U.S. Naval Ord. Lab.); J. Appl. Phys., Vol. 35, pp. 1224-1227, Apr. 1964

The time of maximum switching current t_m of triglycine sulfate (TGS) crystals has been measured as a function of field E and crystal thickness d in the ranges $10^2 < E < 10^3$ V/cm and $0.02 < d < 0.98$ cm. The results may be expressed as $t_m = t_\infty \exp[a_0 d^{-2/3}/E]$ with $t_\infty \simeq (1.3 \pm 0.3) \times 10^{-4}$ sec and $a_0 = (4 \pm 1) \times 10^2$ V/cm. The symmetry of the switching transients about t_m is a function of d and increases slightly with E. The symmetry factor m varies from $m = 0.7$ to $m = 0.4$ for $0.5 < d < 1.0$ cm in agreement with a model for polarization reversal in which the virtual sidewise displacement of domain walls is the dominant mechanism. For thin crystals, $d < 0.15$ cm and $m < 0.1$, a model based on dominant nucleation and growth of antiparallel domains is consistent with experimental observations.

23,907 DYNAMICS OF POLARIZATION REVERSAL IN KH_2PO_4 AND KD_2PO_4 by R.E. Oettel (Boeing and U. Washington); Bull. Am. Phys. Soc., Vol. 9, p. 215(A), Mar. 1964

The line structure previously observed in Z-cut KH_2PO_4 plates has been investigated in more detail. The bounding regions, which extend entirely through crystals of thickness $\simeq 0.1$ cm, are readily visible without polarizers. These boundaries are assumed to be domain walls. A novel method has been used to measure the width between boundaries. Results are in reasonable agreement with that to be expected, on other grounds, for domain widths. Using semi-transparent metal electrodes, the rate of domain-wall nucleation and propagation when a voltage step is applied have been studied. With peak fields of 2 kv/cm, several minutes are required for all domain boundaries to disappear in KD_2PO_4. A very abrupt change in the ease with which domain walls may be moved is observed at 135°K. Below this temperature, no motion is observable with an applied field of several thousand V/cm. Quasistatic hysteresis-loop measurements of spontaneous polarization are presented for both crystals.

23,908 HIGH-TEMPERATURE DC POLARIZATION EFFECTS IN THE ALKALI HALIDES by J.N. Maycock (RIAS); Bull. Am. Phys. Soc., Vol. 9, p. 227(A), Mar. 1964

dc ionic-polarization effects have been observed in the alkali halides in the temperature range 300°C to the melting point. The single-crystal samples of pure alkali halides were subjected to a dc step potential and the resulting transient polarization currents recorded. The current decay times varied considerably with temperature and applied potential, with the fastest decay occurring at the highest temperatures. The polarization currents have been analyzed as a sum of two time exponentials of the form $I_p = A \exp(-\alpha t) + B \exp(-\beta t)$, and from these values of α and β have been obtained. Potentials varying from the order of kT to 100 V/cm have been used to establish the nonlinearity of Ohm's law for these crystals. Crystals doped with aliovalent ions exhibit a very fast current decay, but in general their polarization features are very similar to those of the pure crystals.

23,909 POLARIZATION OF FERROELECTRICS UNDER CONDITIONS OF SHORT-TIME ELECTRIC PULSES by K.N. Karmen (Novocherkassk Land Reclamation Engrg. Inst.); Soviet Phys.-Cryst., Vol. 8, pp. 583-585, Mar.-Apr. 1964

A method for following the variation in magnitude of the charge of a ferroelectric capacitor under the action of a voltage pulse is described. The voltage pulses have a duration of 0.75 to 10 μsec. It is found that the dependence of the polarization on the electric field strength, temperature and prehistory does not vary with reduction in the duration of the electric pulses to several microseconds.

23,910 A STATISTICAL METHOD FOR THE INVESTIGATION OF REPOLARIZATION PROCESSES IN FERROELECTRIC CERAMICS by A.V. Turik (Rostov-on Don State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1751-1753, Mar. 1964

The dynamics of domain repolarization relative to the coercive and internal fields are discussed taking into account the random distribution of the crystallographic axes in the ceramic. Formulas are given for the principal polarization curve and the branches of the hysteresis loop. The behavior of ferroelectrics for the case of simultaneous application of direct and alternating fields is investigated. In very weak or strong fields, no maximum is observed, but simply a smooth increase in the dielectric susceptibility and hysteresis losses.

23,911 EXPERIMENTAL INVESTIGATION OF THE STATISTICAL DISTRIBUTION OF DOMAINS IN A FERROELECTRIC CERAMIC by A.V. Turik (Rostov-on-Don State U.); Soviet Phys.-Solid State, Vol. 5, pp. 2141-2143, Apr. 1964

The Preisach diagrams of some ceramic ferroelectrics have been investigated. The results are explained based on the concepts of surface layers at grain boundaries and local space charge at domain boundaries. In small grains the space-charge fields play the main role in determining the distribution of the internal fields, while in large grains the fields that are related to the regular domain structure have the dominant effect.

Ferroelectricity of $BaTiO_3$ - See 23,806

23,912 DIRECT OBSERVATION OF ANTIPARALLEL 180° DOMAINS IN $BaTiO_3$ BY X-RAY ANOMALOUS DISPERSION METHOD by N. Niizeki and M. Hasegawa (NTT); J. Phys. Soc. Japan, Vol. 19, pp. 550-554, Apr. 1964

Antiparallel domain configurations in c-plate crystal are observed in {003} X-ray reflection micrographs by the intensity contrast caused by anomalous scattering of the incident CrKa radiation by Ba and Ti atoms. The micrographs are taken with the scanning method of Lang applied to the reflection case. The ratio between $|F(00\bar{3})|^2$ and $|F(003)|^2$ measured by a single-crystal-diffractometer amounts to 1.16. It is shown that with this reflection the antiparallel domains can be clearly discriminated in the X-ray reflection images with strong intensity contrast, and that the domain reversal process can be followed non-destructively.

23,913 RANDOM NUCLEATION OF NEW DOMAINS IN $BaTiO_3$ CRYSTALS AT 20 kv/cm by H.L. Stadler and P.J. Zachmanidis (Ford Motor); Bull. Am. Phys. Soc., Vol. 9, p. 215(A), Mar. 1964

The locations of domains appearing on the surface of a $BaTiO_3$ crystal have been observed by repeated partial switching and etching to determine how frequently the domains appear at the same location on successive applied pulses. The ratio of the number of repeating locations to that of all locations is (10 ± 1.6) per cent for a series of 6 pulses at 20 kv/cm on crystals with a positive internal bias and (28 ± 5) per cent on crystals with a negative bias. The simplest interpretation of the results is that new domains can nucleate at points in the crystal remote from imperfections. This interpretation is in rough agreement with Landauer's 1957 calculation of the probability of thermally activated new domains, using a 180° wall energy of 0.4 erg/cm² rather than the 7 erg/cm² assumed by Landauer.

23,914 DIELECTRIC PROPERTIES OF KBr SINGLE CRYSTALS IRRADIATED WITH FAST ELECTRONS by V.V. Krasnopevtsev (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1645-1650, Feb. 1964

A study of the dielectric properties and optical absorption of KBr single crystals subjected to bombardment with electrons of 0.5, 0.75, and 1.0 Mev energies is reported. The F and V_2 centers and defects produced by the bombardment cause the dielectric relaxation which can be described satisfactorily by the Cole-Cole diagram. The mechanisms of defect formation and annealing are discussed.

23,915 PIEZOELECTRIC CERAMICS OF $Pb(Zr-Ti)O_3$ MODIFIED BY $A^{1+}B^{5+}O_3$ OR $A^{3+}B^{3+}O_3$ by T. Ikeda and T. Okano (NTT); Japanese J. Appl. Phys., Vol. 3, pp. 63-71, Feb. 1964

The properties of the solid solutions $(Pb_{1-x}-A_x)(Zr_y-Ti_{1-y})_{1-x}-B_x)O_3$ or $(1-x)Pb(Zr_y-Ti_{1-y})O_3-xABO_3$ are studied, where A is a mono- or trivalent ion and B a penta- or trivalent ion as follows: A^{1+} = K, Na, B^{5+} = Sb, Nb, Bi; A^{3+} = Bi, La, B^{3+} = Fe, Al, Cr. The composition ranges examined are mostly within $x < 0.2$ and $0.4 < y < 0.7$. With the present method of preparation by the solid state reaction, the soluble range lies mostly within about ten mole per cent substitution, but in some cases, for example, for the combination of Bi-Fe or Na-Nb, it spreads much wider. The effects of B ion on the falling of the Curie point and on the shift of the boundary between the tetragonal and rhombohedral phases are discussed. The piezoelectric performances of $Pb(Zr-Ti)O_3$ ceramics are improved by the present modification with ABO_3; that is, the dielectric constant increases and the electromechanical coupling coefficient first increases to a broad maximum and then decreases. The coupling coefficient over 0.5 is easily obtained even for less dense ceramics, especially in the case of $NaNbO_3$ substitution.

23,916 ELECTROSTRICTION IN TRIGLYCINE SULFATE by A.A. Fotchenkov, M.P. Zeitseva and L.I. Zherebtsova (Acad. Sci. USSR); Soviet Phys.-Cryst., Vol. 8, pp. 579-582, Mar.-Apr. 1964

The dependence of the electrostriction coefficient R_{22} on the strength of the alternating electric field and the temperature has been studied for a Y-cut crystal of triglycine sulfate. The results show that at field strengths up to 180 V/cm, piezoelectric strain predominates, and R_{22} increases linearly in the temperature range 20-42°C. The influence of the polarizing field on R_{22} is discussed. The relationships found are explained by the peculiarities of the domain structure and the behavior of this structure in an electric field.

CARRIER PROPERTIES

GENERAL

23,917 NATURE OF CHARGE CARRIERS IN GeTe by N.V. Kolomoets, E.Y. Lev and L.M. Sysoeva (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2101-2105, Apr. 1964

An investigation of the nature of the charge carriers in GeTe on the basis of measurements of its electric properties is reported. It is concluded that the observed electrical properties are the result of its nonstoichiometric composition and are not due to the overlapping of the valence and conduction bands. Within the limits of solubility of the components, the carrier concentration varies from 3×10^{20} to 1.2×10^{21} cm^{-3}.

23,918 DECREASE OF ELECTRON TEMPERATURE BY ELECTRIC FIELDS by V.V. Paranjape (U. Liverpool) and T.P. Ambrose (Trinity Coll.); Phys. Lett., Neth., Vol. 8, pp. 223-224(L), Feb. 15, 1964

The effect of an electric field on electron temperature with scattering by optical modes predominant is discussed. It is shown that with optical scattering only and weak electric fields, the electron temperature T is below the lattice temperature T_0. The mean electronic energy $\langle E \rangle$, however, is larger than $(3/2)kT_0$, and the total energy change $[\langle E \rangle - (3/2)kT_0]$ is always positive.

23,919 PECULIARITIES OF THE ZEEMAN AND STARK EFFECTS OF THE MOTT EXCITON by D.S. Bulyanitsa (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1730-1732(L), Feb. 1964

The variation in the Zeeman and Stark effects of the Mott exciton in comparison with hydrogen is discussed. In the quadratic Zeeman effect, the displacements are positive and increase with the quantum number n of the level approximately as n^4. In the case of hydrogen, the Stark effect is linear, and in the case of allowed transitions, the n = 1 level has a displacement which is negative and quadratic with respect to the field.

23,920 ANALYSIS OF THE POSSIBILITY OF OBSERVING THE BOSE-EINSTEIN EXCITON CONDENSATION IN CRYSTALS OF GROUP $A^{II}B^{VI}$ by V.V. Sobolev (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2216-2217(L), Apr. 1964

Comparison with experimental data of theoretical conclusions based on the assumption that the quasi-equilibrium distributions between excitons are established shows that in order to observe the Bose-Einstein exciton condensation, the resolution of the spectrum apparatus must be very high, the temperature of the crystal must be kept below the critical temperature and the crystal must be extremely pure. It is, however, pointed out that the quasi-equilibrium distributions may not be realized and thus the theoretical conclusions may have to be re-examined.

Exciton Structure of Alkali Halides and Inert Gases (Solid) - See 23,841

Carrier Density:
- at InSb Grain Boundaries - See 23,980
- in Ge - See 24,057
- in TiC_xN_{1-x} and $TiV_{1-x}C$ - See 24,055

Carrier Concentration in:
- $InAs_ySb_{1-y}$ Films - See 24,331
- SnTe - See 23,833
- ZnSb - See 24,323

RECOMBINATION (LIFETIME)

23,921 CONCERNING A POSSIBLE RECOMBINATION MECHANISM by V.L. Bonch-Bruevich and E.B. Sokolova (Lomonosov Moscow State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1986-1987(L), Mar. 1964

The mechanism of recombination in multicharge centers is discussed. It is shown

hat the concept of a recombination mechanism through intermediate excitons oes not agree with experiment, although this mechanism is not impossible in rinciple.

3,922 ON A POSSIBLE RECOMBINATION MECHANISM AT MULTICHARG-D CENTERS IN SEMICONDUCTORS by M.K. Sheinkman (Acad. Sci. UkrSSR); oviet Phys.-Solid State, Vol. 5, pp. 2035-2038, Apr. 1964

possible recombination mechanism for nonequilibrium carriers in a semiconuctor containing multicharged recombination centers is considered. The specil feature of this mechanism is that the capture of a minority carrier by a multcharged center is accompanied by the transfer of one or more carriers of opposite sign from the center to a band. Some experimental consequences which ollow from this mechanism are pointed out.

ecombination Radiation from:
Diamond - See 24,366
GaP Diodes - See 24,370
Ge - See 24,367
PbTe - See 24,371

ecombination Luminescence in:
Alkali Halides - See 24,373
GaP Diodes - See 24,369

3,923 TEMPERATURE DEPENDENCE OF CARRIER LIFETIMES IN InAs by M. . Mikhailova, D.N. Nasledov and S.V. Slobodchikov (Acad. Sci. USSR); oviet Phys.-Solid State, Vol. 5, pp. 1685-1689, Feb. 1964

n investigation of the temperature dependence of carrier lifetimes in n- and -type InAs in the temperature range 80-300°K is reported. It is found that he trapping levels play an important role in determining the lifetimes. A posible mechanism for recombination in InAs is described, which assumes the existence of a multicharged impurity center with an energy of ~0.15 ev. The pectral distribution of photoconductivity at various temperatures was studied. he temperature coefficient of the forbidden gap was found to be -4.1×10^{-4} v/°K.

3,924 ANNEALING OF RECOMBINATION CENTERS IN ARSENIC-DOPED GERMANIUM NEAR ROOM TEMPERATURE by O.L. Curtis, Jr. (Oak Ridge); ull. Am. Phys. Soc., Vol. 9, p. 289(A), Mar. 1964

he annealing behavior of recombination centers induced in As-doped Ge by ^{60}Co gammas at 0°C has been studied. A distinct annealing process occurs hortly above room temperature, which was studied by performing isothermal nneals at 5 temperatures in the range 39° to 84°C. In 1.4-Ω·cm material bout 1/3 of the damage, as indicated by reciprocal minority-carrier lifetime, as stable at these temperatures (this fraction apparently did not depend on emperature of anneal). After subtracting this stable fraction, the annealing urves display first-order time dependence, and the slopes are independent of amage concentration. The first-order rate constants when plotted vs 1/T, fall ery nearly on a straight line, indicating an activation energy for the annealng process of 0.65 ev. The magnitude of the rate constant was dependent on s concentration.

3,925 ON THE INFLUENCE OF CADMIUM ON THE PROBABILITY OF ELECRON RECOMBINATION IN GERMANIUM by E.Yu. L'vova (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2239-2240, May 1964

t is found that cadmium has a weak effect on the recombination velocity in ermanium. At cadmium concentrations of $\sim 10^{14}$ cm^{-3} the electron lifetime reains its high value of ~1000 μsec. An estimate of the upper limit of the effeive electron-capture cross section for cadmium atoms gives a value of $< 1 \times 10^{-17}$ cm^2.

23,926 RECOMBINATION OF CURRENT CARRIERS AT ZINC ATOMS IN n-TYPE SILICON by K.D. Glinchuk and N.M. Litovchenko (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 2197-2198, Apr. 1964

The processes of recombination of current carriers at Zn atoms in n-type Si have been studied by measuring the photoconductivity of the samples. It is found that the electron-capture cross section of Zn^- ions is 10^{-16} cm^2 at 90-200°K. The relatively large value of the cross section and its weak temperature dependence indicate that Coulomb repulsion of electrons by Zn^- ions does not play an important role.

23,927 ELECTRIC FIELD EFFECT ON THE EFFECTIVE RECOMBINATION AND TRAPPING CROSS SECTIONS by V.V. Antonov-Romanovskii (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 979-980, Nov. 1963

The effect of a homogeneous electric field on the effective recombination and trapping cross sections in the presence of diffusion kinetics is discussed. It is shown that the effect of drift on the cross sections can be neglected, and that the electric field has no effect on the cross sections in the case of a dipole or polarizable center.

23,928 EFFECTIVE TRAPPING AND RECOMBINATION CROSS SECTIONS OF FREE CHARGES IN SOLIDS by V.V. Antonov-Romanovskii (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 975-978, Nov. 1963

It is shown that the effective recombination and trapping cross sections of free charges depend not only on the nature of the interacting centers but also on certain kinetic parameters such as the mean free path of mobile charges and the concentration of the centers. Depending upon the experimental conditions, there may exist two different cross sections: the gas dynamic cross section σ', and the diffusion cross section σ, and it is found that $\sigma' \ll \sigma$.

23,929 EFFECTIVE CROSS SECTION FOR ELECTRON CAPTURE BY NEGATIVE IRON IONS IN GERMANIUM by A.D. Belyaev and V.G. Malogolovets (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 2229-2231(L), Apr. 1964

An investigation of the intrinsic photoconductivity kinetics in n-type Ge before and after the introduction of an iron impurity is reported. In samples without iron, the photoconductivity decays exponentially with a single time constant, while in samples with iron, the photoconductivity decay curves exhibit two components with two different time constants. It is shown that the relatively fast time constant is related to the lifetime of electrons recombining at singly-charged iron ions. The temperature dependence of the effective cross section σ_e' has been calculated. It is found that σ_e' is reduced on cooling in the presence of negative iron ions. At T = 300°K, σ_e' is about 10^{-16} cm^2.

23,930 SURFACE RECOMBINATION AT HIGHER INJECTION LEVELS by R. Memming (Philips Res. Lab., Hamburg); Surface Sci., Vol. 1, pp. 88-101, Jan. 1964

The theory of surface recombination has been extended to high deviations from equilibrium. In order to test the theory, measurements of the dependence of the effective surface recombination velocity upon the light intensity have been carried out at a silicon-electrolyte interface. The experimental results are in quantitative agreement with the theory. In this case the Shockley-Read model could be confirmed assuming only one discrete recombination center.

Semiconductor Lifetime - See 23,843

EFFECTIVE MASS AND CHARGE

23,931 INVESTIGATION OF THE TEMPERATURE DEPENDENCE OF THE EFFECTIVE ELECTRON MASS IN n-InAs IN THE REGION 293-603°K by Yu.I. Ukhanov and Yu.V. Mal'tsev (Red-Banner Military Acad.); Soviet Phys.-Solid State, Vol. 5, pp. 1124-1126, Dec. 1963

The temperature dependence of the effective electron mass in n-type InAs has been investigated in the temperature range 293-603°K, using the angle of rotation of the plane of polarization of infrared radiation of wavelengths 10-18 μ. It is found that on heating the sample from room temperature to 393°K, the effective mass increases by 7.0 ± 6 per cent, and on further increase of temperature, it decreases almost linearly. At 603°K, the effective mass is 10 ± 1 per cent less than that at 393°K.

23,932 INVESTIGATION OF THE TEMPERATURE DEPENDENCE OF THE ELECTRON EFFECTIVE MASS IN SEMICONDUCTORS by Yu.I. Ukhanov and Yu.V. Mal'tsev (Military Commun. Acad.); Soviet Phys.-Solid State, Vol. 5, pp. 2144-2149, Apr. 1964

The effective masses of electrons in n-type crystals of Ge, Si, InSb, InAs and GaAs have been determined by the Faraday effect in the temperature range 117-600°K. It is found that the effective masses increase with increasing of temperature for all investigated samples except InAs, for which the effective mass decreases on heating above 400°K. For Ge the effective mass increase by (15 ± 2) per cent in the temperature range 117-600°K. For Si the increase of mass amounts to (11 ± 2) per cent in the range 293-600°K.

Effective Mass:
in Graphite - See 23,847
in Pb - See 23,853
in ZnSb - See 24,323
Ratio in $InAs_ySb_{1-y}$ Films - See 24,331

Cyclatron Mass of Ca - See 23,852

23,933 THE PROBLEM OF THE TEMPERATURE DEPENDENCE OF ELECTRICAL TRANSPORT IN METALS by M.D. Smolin (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1151-1152, Dec. 1963

It is shown that in the case where the effective charge of an ion migrating in the process of electrical transport remains constant in a wide range of temperatures, the effective charge is equal to the actual charge of the ion.

23,934 NON-OHMIC TRANSPORT IN SEMICONDUCTORS IN A MAGNETIC FIELD by D. Matz and F. Garcia-Moliner (Illinois U.); Jan. 6, 1964, 43 pp., Contract Nonr183412; U.S. Gov. Res. Rep., Vol. 39, p. 17(A), Mar. 20, 1964 AD 426 845 OTS $4.60

Shockley's hot electron picture for semiconductors in high electron fields is extended to include arbitrary (though non-quantizing) magnetic fields. While preserving the original simplicity of Shockley's model, its scope can be extended by including a reduction of the power input due to the deflection caused by the Lorentz force. Explicit calculations are carried out for an idealized isotropic model which Conwell used to interpret the experimental data for n-Ge in zero magnetic field. This involves interactions of electrons with acoustic and covalent optical modes. This model calculation is designed to illustrate the main physical features of the extended Shockley picture. The results obtained are used to disucss the kind of information which can be expected from different types of experiments and some suggestions are made for some relevant measurements yet to be done. Other scattering mechanisms are briefly discussed.

23,935 EFFECT OF SPACE CHARGE UPON THE TRANSPORT OF CHARGE CARRIERS by A.L. Ward (Harry Diamond Labs.); J. Appl. Phys., Vol. 35, pp. 469-474, Mar. 1964

Numerical machine calculations have been made on the effect that space charge, composed of mobile charge carriers, has on the drift and diffusion of those carriers in an electric field. An apparent diffusion of carriers arises from the difference equations used to solve the transport problems, even though no diffusion term is included in the transport equations. This calculated diffusion is shown to be exact in the absence of space charge and in the limit of infinitely small calculation intervals. Numerical results illustrating the effect of space charge upon apparent diffusion coefficients and drift velocities are given for a fictitious gas. Calculations show good agreement with experimental data taken in two other laboratories to measure attachment coefficients in gases. Exploratory calculations have indicated the usefulness of this model for calculations in solid-state transport.

23,936 HALL MOBILITY OF PHOTOELECTRONS IN CdS by K. Kobayashi, H. Fujita, T. Kawai (U. Tokyo) and K. Shiga (Matsushita Res. Inst., Tokyo); J. Phys. Soc. Japan, Vol. 19, p. 135(L), Jan. 1964

Measurement of Hall mobility of photoelectrons in CdS is reported. It was observed to be as high as 10^4 cm^2/volt/sec at 5°K; a curve is presented of Hall mobility as a function of temperature. The sign of the Hall effect was due to negative carriers in the entire range of temperature. It was found that Hall mobility did not decrease at low tempertures, but remained approximately constant. A theoretical curve is also plotted and discrepancies occurring at low temperatures are attributed to impurities; high temperature agreement is good.

Hall Mobility of:
ZnSb - See 24,323
UO_2 - See 23,987
CdTe Films - See 23,950

23,937 EFFECT OF ANHARMONICITIES OF HIGH ORDER ON TRANSPORT PROCESSES IN SOLIDS by R.N. Gurzhi; Soviet Phys.-JETP, Vol. 18, pp. 515-518, Feb. 1964

It is shown that at sufficiently low temperatures, transport processes in solids may be determined by anharmonicities of arbitrarily high order. For this it is necessary that the energy of the corresponding quasi-particles vary more rapidly than linearly as a function of the quasi-momentum. A specific calculation is carried out for the spin-wave induced thermal conductivity of ferrites.

Mobility Anisotropy of Si - See 23,974

23,938 TRANSPORT PROPERTIES OF ORGANIC SEMICONDUCTORS by L. Friedman (RCA Labs.); Phys. Rev., Vol. 133A, pp. A1668-1679, Mar. 16, 1964

Electrical and thermal transport coefficients of a large class of organic crystals are calculated from a Boltzmann equation treatment of narrow-band semiconduction. The latter, in turn, is based on the known tight-binding band structure of these crystals, and on an assumed relaxation time τ. Specifically, assuming bandwidths $\lesssim k_0T$, explicit expressions are obtained for the electrical conductivity, Hall constant, magnetoconductivity, thermoelectric power, and thermal conductivity. These are expressed in terms of the relevant intermolecular transfer integrals and τ, for various crystallographic directions. In most cases, the results are carried out to the first order in bandwidth/k_0T. The calculated anisotropy of the electric conductivity agrees satisfactorily with experiment. The Hall constant is found to be anomalous both in magnitude and sign. Finally, it is pointed out that the anisotropy of the thermoelectric power and magnetoconductivity can, in principle, provide information about the band structure.

23,939 INVESTIGATION ON ZONE MELTED ZnSb SINGLE CRYSTALS [in German] by E. Justi, W. Rasch and G. Schneider (Tech. Hoch., Braunschweig); Adv. Energy Conv., Vol. 4, pp. 27-38, Jan-Mar. 1964

The preparation and transport properties of ZnSb single crystals are discussed. The process of preparing single crystals by extremely slow zone-melting (v = 0.28 µsec), the melting zone containing Sb-excess for lowering the melting point under the peritectic temperature, is described. The purest crystals obtained showed a hole concentration of about 2×10^{16} cm^{-3}. The higher mobility of the charge carriers results in an increase of the product $a^2\sigma$; however the thermal conductivity was also raised. Measurements of the Hall coefficient and the electrical conductivity down to liquid helium temperatures show the characteristic properties of impurity band conduction. The magneto-resistance in transverse field becomes negative at the lowest temperatures. Doping experiments were carried out with Ga, Te and Cu. An inversion of AnSb into n-type has not yet been obtained.

23,940 THE TRANSPORT PROPERTIES OF P-TYPE PbTe by M.M. Sokoloski and J.H. Marburger (Stanford U.); Nov. 1963, 42 pp.; STAR, Vol. 2, p. 747(A), Mar. 23, 1964 NASA TM X-51388; X-633-63-233; OTS $4.60 ph, $1.46 mf

Nearly all the elementary parameters that appear in the theoretical expression for mobility can be determined from measurements of transport properties. Measurements of the Hall coefficient give information on the number of charge carriers, the one parameter most likely to vary from sample to sample. Measurements of the conductivity and thermoelectric power give information about the mobility and Fermi level. These measurements provide the basis for quantitative theoretical predictions. This paper discusses how these predictions are made, modifications of the instrumentation, results, and accuracy of the results obtained by this method.

23,941 INVESTIGATION OF THE CARRIER MOBILITY IN NiO WITH Li IMPURITY by Ya.M. Ksendzov, L.N. Ansel'm, L.L. Vasil'eva and V.M. Latysheva (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1116-1123, Dec. 1963

A study of the conductivity, thermoelectric power and Hall effect of $Li_xNi_{1-x}O$ with $0.01 < x < 0.2$ in the temperature range from liquid nitrogen to 300°C is reported. The data are satisfactorily explained within the framework of the usual energy-band model with a narrow polaron band. The Hall effect data and calculation of the drift mobility show that the hole mobility in the polaron band decreases, and the electron mobility at the acceptor levels increases with temperature according to an exponential law.

23,942 CRYSTALLITE SIZES AND CARRIER MOBILITIES IN EVAPORATED INDIUM ANTIMONIDE FILMS by R. Koike and R. Ueda (Waseda U.); Japanese J. Appl. Phys., Vol. 3, pp. 191-196, Apr. 1964

The correlation between crystallite size and carrier mobility of indium antimonide films deposited in a vacuum on glass substrates was studied. The crystallite size was determined from the X-ray diffraction profile, while the carrier mobility was deduced from a dc measurement of the transverse magnetoresistance effect. The data obtained from 50 specimens revealed the existences of a threshold crystallite size for a high mobility film and that the threshold value of this dimension is of the same order of magnitude as the mean free path of the electrons, i.e., 1000A. Some effects of annealing the film on the crystallite size were also investigated.

Mobility of InSb at Grain Boundaries - See 23,980

23,943 MOBILITY OF ELECTRONS IN TiO_2 AND a-Nb_2O_5 AT HIGH TEMPERATURES by J. Yahia (Pennsylvania State U.); Bull. Am. Phys. Soc., Vol. 9, p. 279(A), Mar. 1964

A simple method for measuring the low mobility of oxide semiconductors is by combining thermogravimetric data (yielding density of charge carriers) with electrical-conductivity data. The temperature variation of the electronic mobility $\mu(T)$ in TiO_2 and a-Nb_2O_5 was found using this method. For both substances the mobility is activated and small at temperatures in the vicinity of 1000°K. $\mu(T)$ is found to be $\sim 5 \times 10^{-5}$ cm^2/V·sec for TiO_2 and $\sim 7 \times 10^{-2}$ cm^2/V·sec for a-Nb_2O_5. For rutile, where the appropriate constants are known, the Fröhlich formula for the binding energy of a self-trapped electron in a polar lattice (dynamic case) is used to calculate an energy ≈ 0.6 ev. This is about the observed activation energy. Using a diffusion picture of conductivity, agreement (as to order of magnitude) with the measured mobility at 1000°K is also obtained. The constants are not known for a-Nb_2O_5, so that a calculation of mobility such as the one above cannot be made and compared to experimental values.

23,944 MOMENTUM TRANSFER FROM A SCATTERED ELECTRON TO AN IMPURITY CENTER IN A LATTICE by V.B. Fuks (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1611-1614, Feb. 1964

It is shown that in a periodic lattice, the momentum transfer to the impurity

enter is determined by the change in quasimomentum of the scattered electron, ut not by the change in its mean momentum as is the case for free electrons.

3,945 ANISOTROPIC SCATTERING OF ELECTRONS IN Ge AND Si by I. . Dakhovskii (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1695-699, Feb. 1964

e theory developed previously for the anisotropic scattering of electrons by nized impurities and acoustic phonons is used to calculate the mobility and nisotropy parameter $(m_{\parallel}/m_{\perp})(<\tau_{\perp}>/<\tau_{\parallel}>)$ in Ge and Si in a wide range of mperatures and concentrations of impurities. The results obtained are in good greement with experimental data. The "adjusted" mass is determined for im- urity and mixed scattering. The role played by different scattering mechanisms discussed.

3,946 RANGE OF EXCITED ELECTRONS AND HOLES IN METALS AND EMICONDUCTORS by K. Motizuki and M. Sparks (Stanford U.); J. Phys. oc. Japan, Vol. 19, pp. 486-498, Apr. 1964

ne relaxation frequency for electron-electron scattering of an electron having nergy more than a few k_BT above the Fermi level in a metal is calculated in e Born approximation by assuming a phenomenological Yakawa potential. The me method is then used to calculate the relaxation frequency of a hole hav- g energy more than a few k_BT below the Fermi level in a metal and to cal- ulate the relaxation frequency of an electron in a semiconductor having spher- al energy bands. For electrons in a metal results are compared with the re- lt obtained in a dielectric constant calculation.

3,947 ELASTIC SCATTERING OF NONLOCALIZED MOTT EXCITONS BY ISLOCATIONS by M.A. Ruvinskii (Drogobych Pedag. Inst.); Soviet Phys.- olid State, Vol. 5, pp. 1240-1245, Dec. 1963

he differential effective cross sections for elastic scattering of a nonlocalized ott exciton by edge and screw dislocations are calculated. The relaxation me and free path length are obtained for the case of a screw dislocation. omparison of the exciton scattering by phonons and dislocations shows that e mean free path is determined mainly by exciton scattering by dislocations ven when the two types of scattering are comparable with each other.

3,948 THE DIFFUSION OF EXCITONS IN MOLECULAR CRYSTALS by V. . Agranovich and Yu.V. Konobeev; Soviet Phys.-Solid State, Vol. 5, pp. 99-1001, Nov. 1963

xperimental data obtained by Kazzaz and Zahlan concerning the transfer of lectron excitation energy from the host naphthalene crystals to the anthracene mpurities are analyzed. It is shown the data confirm the assumption that the nergy transfer is brought about by "free" excitons, whose mean free path is etermined either by phonon scattering or by scattering due to lattice defects.

RESISTIVITY (CONDUCTIVITY)

3,949 ELECTRICAL PROPERTIES OF COEVAPORATED CdSe FILMS by F.N. ancia, E.R. Hill and E.L. Lind (Harshaw Chemical); Bull. Am. Phys. Soc., ol. 9, p. 249(A), Mar. 1964

olycrystalline films of CdSe have been prepared by coevaporation of Cd and e and the electrical properties examined as functions of the major preparation ariables. Resistivity increased from 10^5 to 5×10^7 Ω·cm as the substrate tem- erature during evaporation was decreased from 400° to 250°C. Resistivity was ssentially independent of relative evaporation rates of Cd and Se, which were aried by a factor of 10. The films showed n-type conductivity and had mobil- ties of the order of 2 $cm^2/V \cdot sec$. Conductivity vs reciprocal-temperature graphs howed an activation energy of 0.54 ± 0.04 ev for temperatures above 300°K, with slightly higher slopes shown at low temperatures. The activation energy as independent of the preparation variables used. This indicates that the elec- rical behavior is dominated by one major defect or impurity whose concentra- ion is controlled by variations in preparation parameters.

23,950 LOW-RESISTIVITY EVAPORATED FILMS OF CdTe by N.E. Heyerdahl nd D.J. Harvey (Harshaw Chemical); Bull. Am. Phys. Soc., Vol. 9, p. 259(A), Mar. 1964

The preparation of low-resistivity films of CdTe by doping and annealing was examines. Polycrystalline films from 10-100 μ thick were prepared by simul- taneous vacuum evaporation of Cd, Te and various dopants. In, Ga, Al, I, Cu, and Ag were used as dopants. Substrates of lime glass and Mo were used at temperatures between 150° and 450°C. Without further treatment, the dop- ed films exhibited resistivities above 10^6 Ω·cm. Donor-doped films annealed in Cd vapor in sealed tubes exhibited resistivities as low as 500 Ω·cm. How- ever, donor-doped films annealed in Cd vapor by maintenance of a Cd pres- sure during cooling immediately subsequent to the vacuum coevaporation ex- hibited resistivities as low as 5 Ω·cm. Electron Hall mobilities were approxi- mately 20 $cm^2/V \cdot sec$, exhibiting no marked dependence on thickness or resis- tivity. X-ray diffraction patterns and optical transmission were comparable to those obtained for powdered CdTe. It is concluded that the high resistivity com- monly reported for evaporated CdTe films is a result of the vacuum annealing occurring while the freshly evaporated films cool to room temperature.

Conductivity of SiO Films - See 23,887

23,951 THEORY OF ELECTRIC CONDUCTIVITY IN SEMICONDUCTORS IN- CLUDING THE FIELDS OF CHARGED IMPURITY CENTERS by M.E. Frezhepov and S.I. Pekar (Shevchenko State U.); Soviet Phys.-Solid State, Vol. 5, pp. 945-949, Nov. 1963

The current in a semiconductor is calculated by solving the three-dimensional conductivity and diffusion equation which involves in addition to an external field the screened Coulomb fields of the impurity ions. A new term in the ex- pression for the current is found, which is due to the combined effects of the external field and the field of the impurity ions. The result shows that the macroscopic conductivity of an impurity semiconductor is smaller than that of a semiconductor without impurities having the same mobility and carrier con- centration.

23,952 IMPURITY CONDUCTION by P. Gosar and D. Justin (Nuc. Inst. Jo- zef Stefan, Ljubljana, Yugoslavia); STAR, Vol. 2, p. 919(A), Apr. 8, 1964 NIJS-R-419

A theory is presented that explains the impurity conduction in semiconductors that is a consequence of the hopping motion of electrons from the occupied to the adjacent unoccupied donor states. The theory is based on the temperature- dependent Green's functions formalism.

23,953 IMPURITY CONDUCTION IN ARSENIC-DOPED GERMANIUM AND IN ARSENIC-DIFFUSED GERMANIUM LAYERS by J.S. Blakemore (Lockheed) and R.O. Olson (Honeywell Semicon.); Bull. Am. Phys. Soc., Vol. 9, p. 257(A), Mar. 1964

Results are presented on electrical conductivity from 1.8° to 300°K in arsenic- doped Ge samples with As densities ranging from 10^{17} to 3×10^{17} cm^{-3}. The transition from impurity conduction to extrinsic conduction is gradual in As- doped Ge, extending from 4° to 50°K in some of the samples studied. Using a two-step deposition/diffusion technique, arsenic was diffused into high-resis- tivity slabs, and electrical conductance studied in the resulting n-type layers, characterized typically by a junction depth of 10-20 μ and an arsenic surface concentration $\sim 2 \times 10^{17}$ cm^{-3}. Diffused layers show a conductance whose mag- nitude and temperature dependence correlate well with that of uniformly doped samples of similar arsenic content, the agreement being surprisingly close in the impurity-conduction range.

23,954 MICROWAVE INTERACTION WITH A SEMICONDUCTOR POST by D.A. Holmes, D.L. Feucht (Carnegie Inst. Tech.), and H. Jacobs (USAERDL); Solid-State Electronics, Vol. 7, pp. 267-273, Apr. 1964

A theoretical analysis and experimental results are presented for a new micro- wave electrodeless technique for measuring semiconductor conductivity using a circular or square semiconductor post mounted vertically in the center of a rectangular waveguide. The validity of microwave studies of recombination effects in semiconductors using this geometry is also established by showing that there is a linear relationship between transmitted microwave power and excess carrier density for small values of excess carrier density.

23,955 MICROWAVE MEASUREMENT OF CONDUCTIVITY AND DIELECTRIC CONSTANT OF SEMICONDUCTORS by D. Holmes and D. Feucht (Carnegie Inst. Tech.); Proc. IEEE, Vol. 52, p. 100(L), Jan. 1964

A mathematical discussion of propagation constants for a shorted rectangular waveguide inhomogeneously filled with semiconductor slab is presented. Dom- inant mode analysis is in excellent agreement with experimental results although an exact field theory solution for the reflection coefficient between the air filled and inhomogeneous semiconductor filled guide would require higher or- der terms. For a one mode Rayleigh-Ritz approximation, assuming that the square of the propagation constant for a given mode is real, the dominant mode propagation constant becomes

$$\gamma_s^2 \cong \omega^2 \mu_0 \epsilon_0 \left\{ \left(\frac{\lambda_0}{\lambda_c} \right)^2 - 1 - \frac{2t}{a} \left(\epsilon_s - 1 - j \frac{\sigma_s}{\omega \epsilon_0} \right) \right\}$$

23,956 MICROWAVE ABSORPTION IN SILICON AT LOW TEMPERATURES by S. Tanaka, M. Kobayashi, E. Hanamura and K. Uchinokura (U. Tokyo); Phys. Rev., Vol. 134A, pp. A256-264, Apr. 6, 1964

The microwave conductivity of p-type and n-type silicon has been studied at low temperatures at ~9000 Mc/sec. In the impurity conduction range, the

microwave conductivity varies much more slowly than the dc conductivity, becoming orders of magnitude larger in comparison at 4.2°K. Furthermore, the conductivity showed strong non-Ohmic characteristics. The experimental results indicated that the microwave conductivity in the low-concentration range consists of two parts, one the conductivity due to direct absorption process in ionized impurity pairs, which shows saturation at low electric-field intensity, and the other, the conductivity due to hopping process, which does not show a non-Ohmic character. A simple theory of the microwave absorption in the ionized impurity pairs was developed, supporting the experimental conclusions. Theory gives a microwave conductivity due to the direct absorption process of the right order of magnitude and the same temperature dependence as measured. But the relaxation time calculated for the pairs is too long compared with the experimental results. The measured hopping conductivity was compared with calculation and reasonable agreement was obtained. The ratio of the conductivity due to the direct absorption process to the hopping conductivity was calculated and requires that a value for the effective Bohr radius at the boron impurity of 20A must be used instead of the 13A obtained from hydrogenic approximation.

23,957 MEASUREMENT OF THE RESISTANCE OF SINGLE CRYSTALS IN A PULSED MAGNETIC FIELD by N.E. Alekseevskii and V.S. Egorov (Acad. Sci. USSR); Soviet Phys.-JETP, Vol. 18, pp. 309-312, Feb. 1964

A method for measuring low electrical resistances of single crystals at low temperatures in pulsed magnetic fields is described. The method has been used to investigate the galvanomagnetic properties of molybdenum, palladium, rhenium and beryllium.

23,958 A METHOD OF MEASURING BULK RESISTIVITY OF ROD SEMICONDUCTOR WITH ORTHOGONAL FOUR ELECTRODES [in Japanese] by S. Maruyama; J. IEE Japan, Vol. 83, pp. 1955-1959, Nov. 1963

Resistivity has been determined by measuring the potential drop between two potential probes and the current through two stream probes. The principle of this method is applicable to a rod of uniform characteristics produced by the float zone refining process. The measuring probes consist of four electrodes, which are perpendicular to the axes of a rod, and are arranged in such a way as to be orthogonal to each other on the surface of the semiconductor. If the current into the bulk of the semiconductor through two stream probes is I in mA, and potential difference is V in mV, the resistivity ρ in Ωcm can be approximately formulated as $\rho = 10 \times V/I \times r$, where r is the radius of the rod in cm.

23,959 CORRECTION FACTORS FOR RADIAL RESISTIVITY GRADIENT EVALUATION OF SEMICONDUCTOR SLICES by M.P. Albert and J.F. Combs; IEEE Trans., Vol. ED-11, pp. 148-151, Apr. 1964

Accurate determinations of radial resistivity gradients on semiconductor slices, using the four-point probe, can be made only if correction factors for the finite boundary conditions are applied to the measurements. The off-center correction is different from the center correction. Both are necessary for gradient evaluation. These corrections were derived assuming homogeneous material, but are, nevertheless, useful approximations for nonhomogeneous materials. The corrections are given as generalized formulas and are graphed for the 62 and 25 mil probes for the center and 1/8 inch from the edge positions.

23,960 AN APPARATUS FOR MEASUREMENT OF THE ELECTRICAL RESISTIVITY OF REFRACTORIES AT ELEVATED TEMPERATURES by J. Fenerty and C. Smith (Pilkinton Bros., Ltd.); Glass Tech., Vol. 5, pp. 78-81, Apr. 1964

An apparatus is described which enables the electrical resistivity of solids to be measured at temperatures up to 1550°C. The equipment utilizes an ac bridge, normally 100 cps and an electronic null detection device. Results are given for several refractory materials. When the logarithm of the electrical resistivity is plotted against the reciprocal of the absolute temperature the results lie on smooth curves which are almost linear.

23,961 STATIC MEASUREMENT OF SURFACE RESISTANCES by J. Deutsch and H.G. Maier (Siemen and Halske); Entwicklungs Berichte, [in German] Vol. 26, pp. 419-422, Dec. 1963

By measuring the attenuation of electromagnetic waves it is possible to determine the surface resistance of resistive layers in a slotted waveguide. A non-ambiguous relationship exists between attenuation and surface conductance of the layer, if the latter does not exceed 5 mmho.

23,962 ELECTRICAL RESISTANCES OF WIRES OF LOW TEMPERATURE COEFFICIENT OF RESISTANCE USEFUL IN CALORIMETRY (10°-380°K) by G. Furukawa, M. Reilly and W. Saba (Natl. Bur. Stand.); Rev. Sci. Instr., Vol. 35, pp. 113-114(L), Jan. 1964

In a survey of alloy wires at temperatures from 10° to 380°K, the resistance of Evanohm and Karma was found to change considerably less than constantan or manganin below 250°K. While the total changes in resistance over the temperature range were 6 per cent and 10 per cent for constantan and manganin, respectively, the resistance of Evanohm and Karma wires changed by only about 0.9 per cent. When applied to heat capacity measurements, these newer heaters will change in resistance on the average only about 0.003 per cent per minute, enabling power readings at one-minute intervals to better than 0.001 per cent accuracy.

23,963 NON-LINEAR RESISTANCE OF THERMAL AND NON-THERMAL ORIGIN IN BISMUTH AND REHEATED PYROLYTIC GRAPHITE by H.J. Goldsmid and J.M. Corsan (GE); Phys. Lett., Neth., Vol. 8, pp. 221-222(L), Feb. 15, 1964

Nonlinear current-voltage characteristics have been measured in bismuth and pyrolytic graphite at liquid helium temperature in a magnetic field. In a bismuth sample about 1 mm^2 in cross section a single kink ($E_k = 16v\ cm^{-1}$) was observed at the lowest pulse repetition rate (281 cps), with the pulsed current flow (pulse duration constant at 20 μsec) and applied magnetic field H (27 kg perpendicular to the trigonal axis. E_k/H, which Esaki has shown should yield the velocity of sound, is about one-half the velocity of sound in bismuth. At higher pulse repetition rates an additional nonlinearity, attributed to a rapid rise in temperature at the onset of film-boiling in the liquid helium, was observed. In pyrolytic graphite which had been reheated at about 3500°C, a kink was observed at $E_k = 100v\ cm^{-1}$ with H (43 koe) along the trigonal axis, 5 μsec pulses, and a pulse repetition rate of 180 cps. Again, E_k/H (2.3×10^{5} cm/sec) was lower than the velocity of sound in graphite. A resistance change was observed during each pulse because of the rapid rise of sample temperature resulting from the very low specific heat of graphite.

23,964 LOW TEMPERATURE RESISTANCE MINIMUM IN Ag AND Cu WHISKERS by A. Grohman and J. Szymaszek (Polish Acad. Sci.); Acta Phys. Polonica, Vol. 24, pp. 285-287(L), Aug. 1963

The low temperature resistance minimum of Ag and Cu whiskers has been studied. In Cu, the temperature ranged from 19.5°K to 23°K; in Ag, from 5°K to 7°K. The ratio of resistance at room temperature to that at liquid He (R_{300}/R_4) ranged from 7.5-15 for Cu and 20 for Ag. In contrast to the theory treating whiskers as "ideal crystals" without resistance minimum, experimental observation of a minimum points out the possibility of either impurities or a size effect occurring in whiskers.

23,965 LOW-TEMPERATURE ELECTRICAL CONDUCTIVITY AND HALL EFFECT IN ZINC-DOPED GERMANIUM by V.I. Sidorov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2199-2202, Apr. 1964

Measurement of the temperature dependence of the Hall coefficient and conductivity of Ge with Zn impurity of various Zn concentrations (10^{14} to $10^{17}/cm^{-3}$) is reported. The results show that increasing the Zn impurity concentration in Ge leads to the appearance of impurity band conduction along the lower Zn level and a sharp decrease in the effective distance between the upper level and the edge of the valence band. This indicates that a strong interaction between nonhydrogenlike centers in Ge appears even for relatively low concentrations in the range 10^{16} to $10^{17}/cm^{-3}$.

23,966 ELECTRICAL RESISTIVITY OF POLYCRYSTALLINE GADOLINIUM FROM 4 to 375°K by R.V. Colvin and S. Arajs (U.S. Steel); Phys. Status Sol., Vol. 4, pp. 37-42, 1964

The resistivity of Gd between 4 to 375°K has been studied. Gd between 5 and 15°K is proportional to T^n, where $n = 3.73 \pm 0.03$. The magnitude of the value supports an earlier model for magnetic resistivity of Gd that invoked the linear spin wave dispersion law. No anomaly in resistivity was observed at 210°K, which indicates the nonexistence of a ferromagnetic-antiferromagnetic transition proposed in an earlier study. The change in resistivity at the Curie temperature, 293 ± 1°K, is interpreted in terms of a gradual transformation from the ferromagnetic to the paramagnetic state.

23,967 RESISTIVITY OF RUTHENIUM by R.J. Tainish and G.K. White (CSIRO); Canadian J. Phys., Vol. 42, pp. 208-209(L), Jan. 1964

Data on thermal resistivity from 90 to 2°K and electrical resistivity from 293 to 2°K are presented. Comparison with earlier data indicates that discrepancies observed are due to neglecting the crystal anisotropy.

23,968 THE TEMPERATURE DEPENDENCE OF ELECTRICAL RESISTANCE FOR NICKEL HYDRIDE by B. Baranow; (Polish Acad. Sci., Warsaw); Acta Met., Vol. 12, pp. 322-324(L), Mar. 1964

Measurement of the temperature dependence of the electrical resistance of stable nickel hydride in the range of liquid nitrogen temperature to 0°C is described. The influence of hydrogen on phonon-electron scattering, magnetic saturation moment and other factors affecting electrical resistance of nickel is analyzed. The extent of effective filling of d-band vacancies in nickel as a result of the introduction of hydrogen and its effect on electrical resistance is also examined.

969 A NEW TYPE OF LOW-TEMPERATURE RESISTANCE ANOMALY IN LOYS by B.R. Coles (Imperial Coll.); Phys. Lett., Neth., Vol. 8, pp. 243-(L), Feb. 15, 1964

anges observed in the low temperature electrical resistance of dilute Rh-Fe oys are discussed. Increases of resistivity by a factor of almost 3 were ob-ved between 1° and 50°K upon the addition of iron to rhodium. No sharp in resistance at a specific temperature was observed, and the magneto-istance exhibited a normal behavior. In addition, plots of resistivity incre-nt/% Fe vs temperature were composition-independent. These results can-be explained in terms of magnetic ordering. It is suggested that they might explained by the existence of an excited state of the Rh-Fe system in which tual bound states are associated with the iron atoms. The iron atoms then e much stronger scattering of conduction electrons than in the ground state ere no strong resonance exists for electrons at the Fermi level.

970 THE HIGH TEMPERATURE CONDUCTIVITY OF ZnTe IN ZINC VA-R by D.G. Thomas and E.A. Sadowski (Bell Labs.); J. Phys. Chem. Solids, l. 25, pp. 395-400, Apr. 1964

e p-type conductivity of ZnTe has been measured between 700 and 950°C, pressures of zinc between 10 and 400 mm. Equilibrium values of the conduc-ity were attained although some crystals required an initial annealing period the zinc vapor to reach the equilibrium state. The hole concentration given

$$p = 3{\cdot}73 \times 10^{23} P_{Zn}^{-1/3} \exp\left(-\frac{1{\cdot}31 \text{ ev}}{kT}\right)$$

ere P_{Zn} is in mm. From this it is concluded that doubly ionized zinc vacan-s are the acceptors, and that the heat of formation of such a vacancy and aseous zinc atom is 3·95 ev.

971 KINETICS OF CARBON PRECIPITATION IN IRRADIATED IRON. Part ELECTRICAL RESISTIVITY MEASUREMENTS by F.E. Fujita and A.C. Da-sk (Brookhaven Lab.); Acta Met., Vol. 12, pp. 331-339, Apr. 1964

e electrical resistivity changes which occur upon annealing quenched iron-bon (0.011 wt.%) after irradiation at low temperatures in a reactor are com-ed to the changes which occur in unirradiated specimens. In unirradiated cimens two stages of resistivity are noted, one about 170°C, associated with formation of a metastable carbide, and one about 250°C, associated with formation of Fe_3C. In contrast, five annealing stages are observed in the adiated specimens between -80°C and 300°C. These stages are discussed in ms of the migration history of the carbon atoms. It is concluded that the car-n atoms are temporarily trapped by radiation-produced point defects and ve the traps only at a temperature higher than that at which the metastable bide can form. As expected, no resistivity decay process associated with formation of the metastable carbide is observed in specimens irradiated to dosage sufficient to trap all of the carbon atoms.

mperature-Pressure Dependence of the Resistivity of Ba - See 23,546

972 ANELASTIC PIEZORESISTANCE EFFECT IN ALLOYS by B.S. Berry d J.L. Orehotsky (IBM Watson Res. Ctr.); Phil. Mag., Vol. 9, pp. 467-484, ar. 1964

periments are described which establish the existence of a new 'anelastic ezoresistance' effect. The effect consists of a change in the electrical re-tivity of a sample as a result of stress-induced directional ordering. This ange has been detected in polycrystalline Ta-O, Ag-Zn, Ag-In, Cu-Zn d Cu-Mn alloys, which undergo stress-induced ordering by either the Snoek Zener mechanism. Values obtained for the anelastic strain coefficient of sistivity were, with the exception of the Ag-Zn alloys, much larger than the rresponding elastic strain coefficient. This result suggests that in general the ng-range strain surrounding a relaxation center is not an important factor in termining the resistivity contributed by the center. It is shown from formal nsiderations that, for the case of the Snoek relaxation, the anelastic strain efficient of resistivity is an isotropic crystal property. With this result, data tained on Ta-O have been analyzed to yield the two resistivity parameters hich define the anisotropy of the scattering cross section of the interstitial ygen atoms. For current flow parallel and perpendicular to the tetragonal is associated with the interstitial oxygen atoms, it is deduced that the resis-vity is, respectively, 5·7 and 4·8 μohm cm/at.% oxygen.

3,973 EFFECT OF PRESSURE ON THE ELECTRICAL CONDUCTIVITY OF AL-ALI METALS by A. Hasegawa (U. Tokyo); J. Phys. Soc. Japan, Vol. 19, pp. 04-516, Apr. 1964

calculation of the electrical conductivity of alkali metals is carried out with-the limit of the one-electron approximation. The band structure obtained by cm and the phonon spectrum determined by experiments are taken into account the calculation. The absolute values of the conductivity of Li, Na and K at om temperature are evaluated and compared with experiments. The agreement tween the theory and the experiment is reasonably good. The temperature de-pendence of their conductivity is evaluated. In the case of potassium the agreement between the theory and the experiment is quite good down to the very low temperature. In the other two cases, the agreement is reasonably good down to 80°K, but becomes worse at low temperatures. The pressure dependence of their conductivity is also evaluated. The theoretical values $d\ln \rho / d\ln V$ of Li, Na and K are -1.7, 4.4 and 5.1, while the observed values are -0.7, 4.4 and 5.5, respectively.

23,974 PIEZORESISTIVE PROPERTIES OF HEAVILY DOPED n-TYPE SILICON by O.N. Tufte and E.L. Stelzer (Honeywell Res. Ctr.); Phys. Rev., Vol. 133A, pp. A1705-1716, Mar. 16, 1964

The piezoresistance effect has been studied in n-type silicon over the impurity concentration range from approximately 1×10^{15} to 1×10^{20} cm^{-3}. From the analysis of the results, it is concluded that for Fermi energies up to 0.08 ev above the band edge, the total number of states below the Fermi level is correctly given by assuming that the band is parabolic with a density-of-states effective mass equal to that found in pure silicon. The qualitative dependence of the mobility anisotropy on impurity concentration and temperature is determined from the piezoresistance results. From the temperature dependence of the coefficient π_{11}, it is concluded that the deformation potential in n-type silicon increases by approximately 25 per cent between 77 and 300°K. Finally, the π_{44} coefficient is found to increase with increasing impurity concentration at the highest concentrations. This behavior is attributed to the Fermi level approaching the energy of the conduction band at the [100] zone boundary in silicon having an electron concentration of the order of 1×10^{20} cm^{-3}.

23,975 PIEZORESISTANCE OF POLYCRYSTALLINE GERMANIUM FILMS by V.S. Shadrin and A.F. Gorodetskii (Novosibirsk Electrical Engrg. Inst.); Soviet Phys.-Solid State, Vol. 5, p. 2218(L), Apr. 1964

The piezoresistance of polycrystalline germanium films has been calculated for various orientations of the crystallites. The angular coefficient of the piezoresistance is averaged out for cases where the crystallites are oriented at random and are oriented so that the plane of the substrate is parallel to one of the following crystallite planes: (110), (211), (111), (100). The average values of the piezoresistance vary between 45 and 50. Comparison of the calculated values with experimental data indicates that the contribution of inter-grain layers to the piezoresistance is small.

23,976 PRESSURE DEPENDENCE OF THE RESISTIVITY AND HALL EFFECT IN n GaAs by R.J. Sladek (Purdue U.); Bull. Am. Phys. Soc., Vol. 9, p. 258(A), Mar. 1964

Measurements of the effect of hydrostatic pressure (up to 6×10^9 dyn/cm^2) on the electrical resistance and Hall effect of single-crystal samples of n-type GaAs with various carrier concentrations have been made between 195° and 298°K. It was found that both the resistivity and Hall effect of a given sample increased with pressure at comparable rates, indicating that most of the piezoresistance is due to a decrease in carrier concentration. The size of the increase depended on both the magnitude and temperature dependence of the carrier concentration and was as much as an order of magnitude at maximum pressure. Combination of the resistivity data at low pressures with results obtained employing uniaxial stress yield values for the piezoresistance shear coefficients, $\pi_{11}-\pi_{12}$ and π_{44}, which are small as compared to π_{11} or π_{12}, indicating conduction is appreciable only in the (000) minimum. A change in the slope of log ρ or log R_H vs pressure occurs near 2×10^9 dyn/cm^2 under some conditions.

23,977 PIEZORESISTANCE IN p-TYPE GALLIUM ANTIMONIDE by O.N. Tufte and E.L. Stelzer (Honeywell Res. Ctr.); Phys. Rev., Vol. 133A, pp. A1450-1451, Mar. 2, 1964

The piezoresistance effect has been measured in p-type gallium antimonide having a hole concentration of approximately 1×10^{17} cm^{-3} over a temperature range from 77 to 350°K. At 300°K, the values of the piezoresistance coefficients π_{11}, π_{12}, and π_{44} are 5×10^{-12}, -2.4×10^{-12}, and 87×10^{-12} cm^2/dyn, respectively. A germanium-type valence band structure is shown to be consistent with both the piezoresistance results and previous magnetoresistance results, whereas none of the many-valley models are consistent with both measurements.

23,978 VARIATION OF THE ELECTRICAL RESISTANCE OF PbS, PbSe AND PbTe UNDER PRESSURES UP TO 200,000 kg/cm^2 by A.A. Semerchan, N.N. Kuzin, L.N. Drozdova and L.F. Vereshchagin (Acad. Sci. USSR); Soviet Phys.-Doklady, Vol. 8, pp. 982-984(L), Apr. 1964

A study of the variation of the resistance of PbS, PbSe and PbTe under pressures up to 200,000 kg/cm^2 is reported. The results show that at the beginning, the resistance decreases with pressure and passes through a minimum and then increases sharply, passes through a maximum and finally decreases. For a given material, the maximum and minimum resistances are considerably different for samples with different degrees of purity, although the pressures at which the maximum and minimum occur are essentially the same. It is shown that PbS, PbSe and PbTe undergo polymorphic transformation in the pressure range investigated.

23,979 ANISOTROPIC PIEZORESISTANCE OF CADMIUM ANTIMONIDE by T. Kawasaki, T. Ishigura and T. Tanaka (Kyoto U.); Japanese J. Appl. Phys., Vol. 3, pp. 172-173, Mar. 1964

An experimental investigation of the anisotropic piezoresistance of CdSb is reported. When uniaxial tensile stress was applied to the crystal, the relationship of the change of the resistivity to the applied stress was linear up to 2 x 10^7 dynes/cm^2 at 193°K and 293°K. The temperature dependence of the piezoresistance coefficient π_{11} is exhibited. In the temperature range above 220°K remarkable changes in the coefficients were observed; the reversal of the sign of π_{33} occurred near 230°K. This behavior is attributed to the predominance of hole conduction below 250°K and the appearance of the intrinsic region above 250°K.

23,980 GRAIN BOUNDARY CONDUCTANCE IN InSb by R.K. Mueller and K.N. Maffitt (Genl. Mills); J. Appl. Phys., Vol. 35, pp. 734-735, Mar. 1964

Interface conductance, carrier mobility, and carrier density on precisely oriented α and β grain boundaries in InSb have been measured. No change in sheet conductance appeared between 6° and 100°K, indicating a degenerate interface layer. The electron density of 2.5×10^{12} cm^{-2} was nearly two orders of magnitude higher than the net number of positive surface charges. The Hall mobilities given for the α bicrystal and β bicrystal were 1.3×10^4 cm^2/Vsec and 2.3×10^4 cm^2/Vsec. These mobilities are nearly two orders of magnitude higher than the hole mobility observed in germanium boundaries, making the InSb grain boundaries interesting objects for the study of magnetic effects on surface transport.

23,981 THE MEAN FREE PATH OF CARRIERS IN BISMUTH AND IN BISMUTH-ANTIMONY ALLOYS by G.A. Ivanov and A.M. Papov (Gertsen State Pedag. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1040-1041, Nov. 1963

The dependence of the resistivity and Hall coefficient in polycrystalline specimens of Bi and Bi-Sb alloys on the grain size has been investigated. It is concluded that the changes in the resistivity and Hall coefficient are caused by the limitation of the mean free path of the carriers by the grain boundaries of the specimens.

Stacking Fault Effects on Resistivity of Cu-Ni and Co-Ni - See 23,695

23,982 OXYGEN VACANCIES AND ELECTRICAL CONDUCTION IN METAL OXIDES by C.J. Kevane (Arizona State U.); Phys. Rev., Vol. 133A, pp. A1431-1436, Mar. 2, 1964

Oxygen vacancies and their effects on electrical conduction in some metal oxides have been considered through an exact solution of the equilibrium relations between oxygen partial pressure in the ambient gas and concentrations of oxygen vacancies and conduction electrons in the oxide. The mass-action law was assumed but no state of ionization of oxygen vacancies was neglected. Concentrations of electrons in conduction states and total oxygen vacancies were considered. The results, which possess considerable complexity not contained in the usual limiting-case solutions, are compared with pertinent experiments.

23,983 MECHANISM OF THE EFFECT OF MICROWAVES ON THE ELECTRICAL CONDUCTIVITY OF n-TYPE InSb AT LOW TEMPERATURES by V.A. Danilychev and B.D. Osipov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1724-1726(L), Feb. 1964

Measurements of the dependences of the sensitivity of n-type InSb receivers on the temperature and electric field are reported. The result shows that the governing mechanism of the electrical conduction is the conduction process in the impurity band, and is not connected with either the photoconductivity or the heating of the free-electron gas by an electric field.

23,984 THE CHANGE OF RESISTIVITY OF Rh AFTER COLD WORK by J.G. M. Van Kuijk (Tech. Hog., Delft); Physica, Vol. 30, pp. 398-400(L), Feb. 1964

A study of the annealing kinetics of 99.99% pure Rhodium wire after cold work (extension) at -196°C and isochronous annealing by pulse annealing at different temperatures is reported. The annealing step between 100° and 440°C is found to take almost 70% of extra resistivity. This is thought to be quite a large percentage to be recovered for a point defect annealing, in comparison with copper.

23,985 RECOVERY OF THE RESISTIVITY OF Pt AFTER DEFORMATION AT LOW TEMPERATURE by L. Menting (Tech. Hog., Delft); Physica, Vol. 30, pp. 407-409(L), Feb. 1964

Recovery of resistivity of Pt wires after stretching and rolling in liquid nitrogen is described. Four stages of recovery were noted, the largest stage (~64% $\Delta\rho_0$) occurring in the range of 180 to 580°C. Annealing kinetics of Pt are compared with those of Cu, Ag and Au.

23,986 CHANGES IN THE CONDUCTIVITY TYPE IN RUTILE CERAMICS A[ND] RUTILE SINGLE CRYSTALS DURING ELECTRIC AGING by V. Ya. Kunin, Y[u.] N. Sedunov and A.N. Tsikin (Kalinin Polytech. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 2028-2030, Apr. 1964

Experiments on the determination of the type of conductivity in ceramic rutil[e] before and after electric aging are discussed. It is found that before aging th[e] ceramic has p-type conductivity; while under the action of an electric field n-type conduction appears. The electrical aging is due to the formation of ne[w] donor defects in the crystal lattice of titanium dioxide.

23,987 ELECTRONIC CONDUCTION IN SINGLE CRYSTALS OF URANIUM DIOXIDE by P. Nagels, J. Devereese and M. Denayer (S.C.K.-C.E.N.-Mol, Belgium); J. Appl. Phys., Vol. 35, pp. 1175-1180, Apr. 1964

Electrical conductivity measurements between 90° and 800°K have been performed on single crystals of uranium dioxide with compositions in the range $UO_{2.000}$-$UO_{2.007}$. The activation energy calculated from the lnσT vs 1/T curv[e] decreases from 0.34 to 0.19 ev with increasing excess oxygen content. Hall e[f]fect measurements by dc and ac techniques yielded no measurable response, a[s] indicate that the Hall mobility is smaller than 0.015 cm^{2}V^{-1} sec^{-1} at room tem[p]erature. This result and a consideration of the fundamental parameters determining the transport mechanism suggest an interpretation based on small polar[on] theory.

23,988 ORDER-DISORDER AND IONIC CONDUCTIVITY IN CUBIC ZrO_2-CaO by E. Subbaras and P. Sutter (Westinghouse Res. Lab.); J. Phys. Chem. Solids, Vol. 25, pp. 148-150(L), Jan. 1964

Order-disorder phenomena and associated ionic conductivity changes in ZrO[2]-CaO systems have been studied. The log σ vs 1/T reveals the existence of diso[r]dered and ordered states and shows that by appropriate heat treatment cycles [the]se states may be changed. Conductivity changes with time during order-diso[r]der transitions confirms that conductivity change is only due to an order-diso[r]der phenomenon and not to the precipitation of a second phase.

23,989 IONIC CONDUCTIVITY OF CUBIC SOLID SOLUTIONS IN THE SY[S]TEM CaO-Y_2O_3-ZrO_2 by D. Strickler and W. Carlson (Westinghouse Res. Lab[s.]; J. Am. Ceramic Soc., Vol. 47, pp. 122-127, Mar. 21, 1964

The ionic conductivity of cubic solid solutions in the system CaO-Y_2O_3-ZrO_2 [w]as examined. Particular Y_2O_3-ZrO_2 binary compositions were more conductiv[e] at elevated temperatures (> 600°C) than either CaO-ZrO_2 binary or CaO-Y_2O_3-ZrO_2 ternary compositions. The higher ionic conductivity appears to be relate[d] to a lower activation energy rather than to the number of oxygen vacancies di[c]tated by composition. Those compositions of highest conductivity lie close to [t]he cubic-monoclinic solid-solution phase boundary. Conductivity-temperatur[e] data are presented that indicate a reversible order-disorder transition for Y_2O_3-ZrO_2 cubic solid solutions containing 20 and 25 mol pct Y_2O_3. The transferenc[e] number for the oxygen ion at 1000°C for Y_2O_3-ZrO_2 cubic solid solutions is greater than 0.99.

23,990 EFFECT OF HYDROSTATIC PRESSURE ON THE STRUCTURE-SENSITIV[E] IONIC CONDUCTIVITY IN KCl by W.B. Daniels, W.H. Taylor, II, B.S.H. Royce and R. Smoluchowski (Princeton U.); Bull. Am. Phys. Soc., Vol. 9, p. 228(A), Mar. 1964

The ionic conductivity of "pure" (Harshaw) and "doped" (10^{-4} mole fraction Sr^{2+}) KCl has been measured at several temperatures in the structure-sensitive range (50°-300°C) up to pressures of 4 kbar. The results from Harshaw KCl show three distinct regions that can be identified as extrinsic unassociated, extrinsic associated, and precipitation. From these data, the volume of motion of free-cation vacancies in KCl was found to be 8.6 cm^3/mole and the volume of association of a divalent impurity-cation vacancy pair 3.6 cm^3/mole. The volume of solution of divalent impurities from measurements in the precipitation region is not constant but is found to increase from 6 to 10 cm^3/mole with decreasing temperature. The results from "doped" KCl show none of the structure seen in "pure" KCl in this temperature range. The behavior of this material in this temperature range is attributed to precipitation of the Sr^{2+} impurity.

23,991 ELECTRICAL RESISTIVITY OF THE PALLADIUM-DEUTERIUM SYSTEM by R.J. Smith (NASA Lewis Res. Ctr.) and A.I. Schindler (NRL); Bull. Am. Phys. Soc., Vol. 9, p. 294(A), Mar. 1964

The electrical-resistivity results of the Pd-D system for D/Pd atom ratios >0.5 are similar in part to the Pd-H system. Between 40° and 77°K, a maximum in the ρ vs T curve is found. In this region, it may require up to 2 h for ρ to reach an equilibrium value. Following deuterium desorption, dρ/dT is less than its value prior to absorption at all temperatures, but irregularities may still appear between 40° and 77°K. It is found that these irregularities disappear over a period of time. The maximum in ρ, before desorption, is due to the transition of the deuterium ion from octahedral to tetrahedral lattice sites. The irregularities in dρ/dT after desorption are explained by assuming the existence of small regions of high deuterium concentration from which the deuterium gradually diffuses into the bulk of the specimen.

,992 ELECTRONIC TRANSPORT IN STRONTIUM TITANATE by H.P.R. ederikse, W.R. Thurber and W.R. Hosler (Natl. Bur. Stand.); Phys. Rev., ol. 134A, pp. A442-445, Apr. 20, 1964

he conductivity and the Hall and Seebeck coefficients of reduced and doped rontium titanate were measured over the temperature range 4.2-300°K. An verage effective mass of about 10 m_0 was deduced from these experiments. his value agrees well with the results of a recent energy-band calculation for TiO_3 based on a tight-binding approximation. Phonon-drag contributions to e Seebeck coefficient appear to be negligible above 50°K. Such a result is xpected in view of the very small heat conductivity reported by Sievers.

,993 SEMICONDUCTING PROPERTIES OF CHROMIUM DISILICIDE by D. inoda, S. Asanabe and Y. Sasaki (Nippon Electric); J. Phys. Soc. Japan, ol. 19, pp. 269-272, Mar. 1964

he electrical resistivities, Hall coefficients and thermoelectric powers of un- oped, Si-doped and Mn-modified $CrSi_2$ crystals have been measured over the mperature range from 90°K to 1100°K. The undoped crystal is a p-type semi- onductor with the hole concentration of about $4 \times 10^{20}/cm^3$. The hole concen- ation is decreased by doping with silicon or manganese. Manganese atoms act donors. Specimens heavily doped with manganese are n-type at low temper- ures and change to p-type at high temperatures. Analysis of the experimental sults leads to the following conclusions: (1) the forbidden energy gap = 0.35 , (2) the ratio of the electron mobility to the hole mobility $\simeq 0.01$ and (3) e density of state effective mass of electrons $\simeq 7\ m_0$ and that of holes $\simeq 5\ m_0$. ssuming that the effective masses and the mobility ratio do not vary with tem- erature, the temperature dependence of the thermoelectric powers of the un- oped and doped crystals can be explained satisfactorily.

,994 ELECTRICAL RESISTIVITY, HALL COEFFICIENT, AND THERMOELEC- IC POWER OF $AuSb_2$ AND Cu_2Sb by W.B. Pearson (Natl. Res. Council, Ot- wa); Canadian J. Phys., Vol. 42, pp. 519-525, Mar. 1964

he electrical conductivity and absolute thermoelectric power of $AuSb_2$ and u_2Sb have been measured between 2.5° and 300°K. Room-temperature Hall oefficients were also determined. Iron impurity causes a giant diffusion ther- oelectric power at low temperatures in the compound Cu_2Sb, as it has previ- usly been found to do in Cu, Ag, and Au.

,995 BARIUM ZIRCONATE MODIFIED WITH LANTHANUM, A HIGH- EMPERATURE CAPACITOR DIELECTRIC by J. Koenig and B. Jaffe (Clevite); . Am. Ceramic Soc., Vol. 47, pp. 87-89, Feb. 21, 1964

he electrical properties of $BaZrO_3$ containing 2-6 at. pct La were investigat- d. Room temperature dielectric constants at 1 Mc were about 43 and the mean mperature coefficients of κ were about -240 ppm per °C. The admixture of a^{3+} raised the volume resistivity by several orders of magnitude. Values as igh as 10^{11} ohm-cm were observed at 500°C. Q values at 1 Mc and 500°C nged from 100 to 400. Breakdown strengths as high as 680 volts per mil were easured for specimens 10 mils thick. The mechanism was indicated to be p- ype, with La^{3+} improving resistivity by lowering the hole concentration.

,996 RESISTIVE ANOMALIES ASSOCIATED WITH LOCALIZED MOMENTS y M.P. Sarachik and E. Corenzwit (Bell Labs.); Bull. Am. Phys. Soc., Vol.9, p. 211-212(A), Mar. 1964

he resistivity has been measured between 1.5° and 77°K for a series of Mo- Nb and Mo-Re alloys containing 1% Fe. It is found that the anomalies typical f dilute transition-metal impurities occur only for those alloys in which the on exhibits a localized moment. Proceeding from Nb to Mo to Re in closely paced alloy compositions: a minimum is first observed for $(Mo_{0.6}Nb_{0.4})_{0.99}Fe_{0.01}$; he minimum is accompanies by a maximum at lower temperature at $(Mo_{0.98}Nb_{0.02})_{0.99}Fe_{0.01}$; the Mo-Re alloys exhibit a decrease in resistivity at ow temperature but no minimum. The deepest minimum is observed at 36°K for he alloy $(Mo_{0.8}Nb_{0.2})_{0.99}Fe_{0.01}$, for which it has been found that the virtual ound state associated with the iron impurity lies at the Fermi energy.

esistivity of:
- $BaTiO_3$ - See 23,893
- Bi-Sb - See 24,045
- Li Ferrite-Chromite - See 24,164
- PbTe-SnTe - See 23,832

Conductivity of:
- Bi_2Te_3 - See 24,053
- NiO(Li) - See 23,941
- Organic Semiconductors - See 23,938
- ZnSb - See 23,939

23,997 THEORY OF CURRENT INSTABILITY IN SEMICONDUCTORS AND SEMIMETALS by L.E. Gurevich and I.V. Ioffe (Acad. Sci. USSR); Soviet Phys.- Solid State, Vol. 5, pp. 1954-1958, Mar. 1964

The current instability in semiconductors is discussed. A qualitative explanation for the phenomenon of current instability is offered, and the minimum electron field necessary to quench the fluctuations is determined. It is shown that the instability created bears a special character and the excited frequency bandwidth is found. It is demonstrated that the theory derived can be extended to the case of the current instability in bismuth.

23,998 INSTABILITIES OF CURRENT IN III-V SEMICONDUCTORS by J.B. Gunn (IBM); IBM J. Res. and Dev., Vol. 8, pp. 141-159, Apr. 1964

A description is given of a newly discovered phenomenon which is observed when an electric field of a few thousand V cm^{-1} is applied to a homogeneous sample of n-type GaAs or InP. Above a well-defined threshold field, a time-dependent decrease in current is observed, which is largely independent of external circuit conditions. In long specimens this decrease in aperiodic, resembling random noise with a bandwidth of $\sim 10^9$ c/sec. In short specimens, coherent oscillations are observed whose period is equal to the transit time of electrons between the ohmic electrodes of the structure. Frequencies over the range 0.5-6.5 Gc/sec have been generated in this way, using experimental techniques which are described. Measurements of the efficiency of dc-to-rf conversion (from 1 to 2%), and of peak power outputs (up to 0.5 W), suggest that the new effect may have useful applications. Some diagnostic experiments are described and the results are discussed in terms of various possible mechanisms. Although the quantitative agreement with theory is poor it is concluded that the current instability may possibly be due to the amplification of lattice optical modes.

23,999 A NEW TYPE OF OSCILLATIONS IN GERMANIUM UNDER THE MAGNETIC FIELD by K. Komatsubara, N. Takasugi and H. Kurono (Hitachi Central Res. Lab.); Japanese J. Appl. Phys., Vol. 3, pp. 72-81, Feb. 1964

A negative resistance characteristic is observed in compensated germanium at liquid helium temperature. The sustaining field strength is changed by the transverse magnetic field. A new type of oscillation phenomenon is observed at the sustaining region when a magnetic field over a critical value is applied. Samples were prepared from a highly compensated germanium single crystal and shaped in the form of rectangular bars. The oscillation frequency, ω, is dependend on the crystal orientation with respect to the magnetic field and the current directions. The empirical formula relating the oscillation frequency to the cross section of a sample, L^2, a magnetic field strength, H, and a majority impurity concentration, N_m, is given by

$$\omega \propto \frac{N_m^{1/3} H}{L^2} \sim \frac{H}{r_m L^2}$$

where r_m is the mean separation of a majority impurity atoms.

24,000 NEW TYPE OF OSCILLATIONS IN InSb by H. Ikoma, I Kuru and K. Hataya (Tokyo Shibaura Electric, Ltd.); J. Phys. Soc. Japan, Vol. 19, p. 238(A), Feb. 1964

The discovery of coherent and incoherent current oscillations in p-InSb at 77°K in a transverse magnetic field with frequencies of 10 or 50 Mc/sec is reported. The frequencies and wave forms of these oscillations are found to vary with the magnitude of the magnetic field beyond a critical value for current oscillation. No appreciable current oscillation was noted in the longitudinal magnetic field or in the absence of magnetic field.

SUPERCONDUCTIVITY

24,001 REPULSIVE BARDEEN-COOPER-SCHRIEFFER PAIR-INTERACTION by K. Sawada and C. Warke (U. California, San Diego); Phys. Rev., Vol. 133A, pp. A1252-1256, Mar. 2, 1964

With the mere use of the sum rules, the effect of interaction on the energy and one-particle momentum distribution of a system of Fermi particles, interacting with the repulsive BCS-type pair interaction, is investigated with the assumption that the coupling constant is of order one, together with the case when the coupling constant is of the order $1/\Omega$ (Ω being the volume of the quantization box) which was treated earlier by Van Hove in connection with the question of sharpness of Fermi surface. It is observed that in some region of density, this type of interaction has no effect on the energy and sharpness of the Fermi sphere, and above critical density the system will go over a phase change, but still the Fermi sphere remains rigid.

24,002 THE ONSET OF SUPERCONDUCTIVITY by A.J. Coleman (Queen's U., Ontario); Canadian J. Phys., Vol. 42, pp. 226-227(L), Jan. 1964

A new condition for the onset of superconductivity is discussed. The condition is that the ratio of occupation density to the density of states be of the order of q_{n-1} for the same ϵ, where n is the number of electrons of the system and ϵ is the energy level. This condition is applicable to "gap-less" superconductors and is considered more satisfactory than BCS theory in which a special provision has to be made for gap.

24,003 AN EXISTENCE THEOREM FOR THE BCS INTEGRAL EQUATION by F. Odeh (IBM); IBM J. Res. and Dev., Vol. 8, pp. 187-188(L), Apr. 1964

The special case of negative phonon interactions in the Bardeen-Cooper-Schrieffer (BCS) theory of superconductivity is discussed. It is shown how the questions of existence and uniqueness of the BCS Integral Equation may be decided by means of descriptive geometrical arguments. It is primarily concerned with the qualitative aspects, rather than the actual calculation of the energy spectrum gap function.

24,004 MICROSCOPIC DERIVATION OF THE GINZBURG-LANDAU EQUATIONS FOR AN ANISOTROPIC SUPERCONDUCTOR by L.P. Gor'kov and T.K. Melik-Barkhudarov (Acad. Sci. USSR); Soviet Phys.-JETP, Vol. 18, pp. 1031-1034, Apr. 1964

A microscopic derivation of the Ginzburg-Landau equations for an anisotropic superconductor is presented. The meaning of the constants encountered in the phenomenological theory and defined in terms of the energy gap at absolute zero is clarified.

24,005 BULK SOLUTION OF GINZBURG-LANDAU EQUATIONS FOR TYPE II SUPERCONDUCTORS: UPPER CRITICAL FIELD REGION by W.H. Kleiner, L.M. Roth and S.H. Autler (Lincoln Lab.); Phys. Rev., Vol. 133A, pp.A1226-1227, Mar. 2, 1964

A solution of the Ginzburg-Landau equations of the Abrikosov type for a homogeneous type II superconductor just below the upper critical field is given. This solution is characterized by magnetic field maxima corresponding to an equilateral triangular lattice and a value $\beta = 1.16$ of Abrikosov's parameter. Abrikosov's square-lattice solution with $\beta = 1.18$ has a higher free energy and is unstable with respect to the triangular lattice solution.

24,006 MODEL WITH SUPERCONDUCTING SOLUTION IN QUANTUM FIELD THEORY II by G. Kuti and G. Marx (Roland Eotvos U., Budapest); Acta Phys., Vol. 17, Nos.1-2, pp. 125-155, 1964

The energy spectrum of a self-coupled scalar field with two separate ground states is calculated using the variational method of Ritz. Two types of interacting particles are obtained. Their energies turn out to be finite after a suitable mass renormalization. Finally, the possible physical consequences of the model are discussed.

24,007 SIMPLE MODEL FOR THE SUPERCONDUCTIVITY OF LANTHANUM AND URANIUM by C.G. Kuper, M. A. Jensen and D.C. Hamilton (U. California, San Diego); Phys. Res., Vol. 134A, pp. A15-21, Apr. 6, 1964

It is postulated that La and U have a narrow f band above, but very close to, the Fermi surface. An exchange interaction, antiferromagnetic in sign, between electrons in the f band can lead to nonzero occupation of the f levels in a BCS-type wave function. This f-band condensation, through a weak coupling of the f band to the conduction band, enhances a BCS condensation of the conduction electrons. There are two energy gaps, for quasiparticle excitations in the two bands. The critical field at zero temperature is calculated, as is the transition temperature. The predicted isotope effect is extremely small. The ratio between the transition temperature and the energy gap at $T = 0$ depends on the numerical values of the parameters; although this ratio is of order unity, it would not be expected to be too near the BCS value of 1/1.75.

24,008 A FIELD-THEORETICAL METHOD IN THE THEORY OF SUPERCONDUCTIVITY by A. Zawadowski (Cen. Res. Inst. Phys., Budapest) and G. Pocsik (Roland Eotvos U., Budapest); Acta Phys., Vol. 17, Nos.1-2, pp. 223-228, 1964

The exact equations concerning the spectral functions of the simplest correlation functions appearing in the theory of superconductivity are derived. As an application it is shown that in the pole-approximation the equations lead to Gorkov's results.

24,009 SUPERCONDUCTIVITY IN MANY-VALLEY SEMICONDUCTORS AND IN SEMIMETALS by M.L. Cohen (U. Chicago); Phys. Rev., Vol. 134A, pp. A511-521, Apr. 20, 1964

It is shown that the attractive electron-electron interaction arising from the exchange of intravalley and intervalley phonons can be larger than the repulsive Coulomb interaction in many-valley semiconductors and semimetals and can cause these materials to exhibit superconducting properties. The importance of observing a superconducting transition in these materials and the properties required of a semiconductor or semimetal to maximize its superconducting transition temperature are discussed.

24,010 ANISOTROPIC SUPERCONDUCTORS WITH NONMAGNETIC IMPURITIES by P. Hohenberg (Acad. Sci. USSR); Soviet Phys.-JETP, Vol. 18, pp. 834-839, Mar. 1964

The properties of weakly anisotropic superconductors containing nonmagnetic impurities are considered. The dependence of the critical temperature, the energy gap and the nuclear spin relaxation time on the concentration of impurities is determined and the effect of impurities on the density of states as functions of energy and direction is discussed. It is shown that the impurities lead to an isotropic density of states at comparatively small impurity concentrations (this corresponds to mean free path ~ correlation length).

24,011 VAPOR-DEPOSITED SUPERCONDUCTIVE FILMS OF Nb, Ta, AND V by C.A. Neugebauer and R.A. Ekvall (GE Res. Lab.); J. Appl. Phys., Vol. pp. 547-553, Mar. 1964

The strong gettering action for oxygen or oxygen-containing gases displayed Nb, Ta, and V was used to reduce the partial pressure of these gases in a vacuum system; and allowed deposition from the vapor of superconducting thin fil of these metals even at pressures of the residual gases higher than 10^{-5} Torr p vided elevated substrate temperatures were used. Critical temperatures of the films were as high or higher than those of the bulk materials; the highest valu were $T(Nb) = 9.81° \pm 0.05°K$, $T(Ta) = 4.51° \pm 0.05°K$, $T(V) = 6.02° \pm 0.1$ Electron tunneling experiments demonstrated that the size and temperature de pendence [$\epsilon(0) = 3.5 T_c$] of the energy gap of these films is in good agreeme with the BCS theory. Critical current vs magnetic field measurements at 4.2° indicate that Ta films go normal at 220-240 oe and Nb films at 9-15 oe. Filr of Nb prepared at low-substrate temperatures displayed inflated lattice paran eters and were not superconductors.

24,012 SUPERCONDUCTIVITY IN SUPERIMPOSED LEAD-PLATINUM FILMS by J.J. Hauser and H.C. Theuerer (Bell Labs.); Bull. Am. Phys. Soc., Vol.9 p. 253(A), Mar. 1964

Superimposed films of platinum and lead were deposited on glass substrates kep at 77°K. The actual metal surface temperature measured with a thin-film thee mocouple was 150°K. The sandwiches were always kept at 77°K until measur ment to minimize interdiffusion. The possibility of interpenetration during dep sition is fairly unlikely, but has not been ruled out by any wholly convincing experiment. The resistivity at 4.2°K of platinum and lead films thinner than 1000A was about 30×10^{-6} Ω·cm. The superconducting transition temperature was measured resistively as a function of the thickness of the two films formin the sandwich. The penetration distance of the electron pairs on the platinum side k_1^{-1} is approximately 80A from the preliminary measurements made so far. Assuming N = 0.4 electron/atom, the mean free path of the platinum become 50A. Using the formula $k_1^{-1} = (\hbar v_F l/6\pi k_B T)^{1/2}$, based on a simple free-electr calculation, $k_1^{-1} \cong 180$A. On the other hand, calculating k_1^{-1} from specific heat measurements gave 45A. The difficulty in estimating k_1^{-1} that arises from the two bands of platinum prevents, at this time, a final conclusion to be drav about the nature of the electron-electron interaction in platinum.

24,013 SIZE EFFECTS IN THIN FILMS OF V_3Ge, Nb AND Ta by J.J. Hause and H.C. Theuerer (Bell Labs.); Phys. Rev., Vol. 134A, pp. A198-205, Apr. 1964

An enhancement of the critical field of V_2Ge, Nb, and Ta has been achieved by reducing the effective coherence length of these materials. This change in the coherence length was obtained in Nb and Ta by changing the grain size ar therefore, the mean free path of the bulk material. Such a study yields also an experimental estimate of the coherence length of the bulk material. Thin films of V_3Ge, Nb, and Ta have been obtained in thicknesses ranging from 200,00C to 100A. The critical temperatures of the films were approximately that of the bulk, although the thinner films always displayed slightly lower critical tempe atures. The transition field of the films was found to increase as the thickness of the films decreased. In conjunction with the transition field increase, a cor responding increase in the residual resistivity was observed, which implies a re duction in the mean free path. The departure of the transition magnetic field from the bulk value occurred at such large thicknesses (a few 10,000A) that such a size effect cannot be explained in terms of the film thickness becoming comparable with the coherence length. This effect can be interpreted in terms of the very small grain size produced by sputtering films which, in turn, leads to a mean free path well below 100A. The presence of a sufficiently small grai size provides a means to produce negative surface energy superconductors with decreasing mean free path and consequently increasing κ without the addition of alloying elements.

24,014 MAXIMUM AVERAGE ENERGY DENSITY AS THE CRITERION FOR PHASE TRANSITION IN THIN SUPERCONDUCTIVE FILMS by K.L. Cheng (Burroughs); J.Appl. Phys., Vol. 35, pp. 1302-1305, Apr. 1964

For recent experimental results on thin superconductive films, the maximum average energy density as a macroscopic criterion of superconductivity is in bette agreement with observed behavior than are any of the earlier criteria - maximu magnetic field, maximum current density, or maximum energy density. The ear ier criteria are briefly reviewed, and characteristic formulas and critical curve are applied to an example for comparison with the proposed criterion. To deter mine the full significance of the proposed criterion, further experimental and theoretical work is needed.

24,015 CHANGE OF ENERGY GAP WITH A MAGNETIC FIELD IN SUPERCONDUCTING FILMS by C. Di Castro and J.G. Valatin (U. Birmingham); Phys. Lett., Neth., Vol. 8, pp. 230-231(L), Feb. 15, 1964

Functional relationships for the variation with magnetic field parallel to the film surface of the gap parameter Δ in very thin and very thick superconducting films are derived. For thin films ($L \leq 50$ A for Sn) $\Delta = 2\omega \exp(-a - b\,H^2/(a' - b'\,H^2)$, where $a = 1/N(0)\,V$, $a' = \pi A_F/L\,k_F$, b and b' are more involved expressions, and H is the magnetic field. Typical values for a Sn film 50A thick are $a \approx 4.0$, $a' \approx 1$, $b \approx 0.84 \times 10^{-12}$ (gauss)$^{-2}$, $b' \approx 1.16 \times 10^{-12}$ (gauss)$^{-2}$. For thick films ($L \gg 500$A for Sn), $1/N(0)\,V = \log 2\,\omega/\Delta - a^2[1/4\,\pi^2\,2\omega/\Delta - (A + \log 2\omega/\Delta)]$, defines the magnetic field strength.

24,016 TIME EFFECTS IN SUPERCONDUCTIVITY by J. Lowell and K. Mendelssohn (Clarendon Lab., Oxford); Cryogenics, Vol. 4, p. 48(L), Feb. 1964

Experimental evidence indicating the slow return to normal resistance of superconducting specimens in fields up to 100 per cent in excess of the critical value is reported. Most of the measurements were done in longitudinal fields. Time constants on the order of 30 minutes were obtained. It is suggested that the effect may be due to the existance of a layer on the geometrical surface of the material which retains a finite resistivity leading to "semi-persistent" shielding currents. Results of limited tests favor this model. Note is made that this effect leaves the validity of critical values measured in pulsed external fields in doubt.

24,017 RESISTIVE TRANSITIONS AND SURFACE EFFECTS IN TYPE-II SUPERCONDUCTORS by C.F. Hempstead and Y.B. Kim (Bell Labs.); Phys. Rev. Lett., Vol. 12, pp. 145-148(L), Feb. 10, 1964

Resistive transitions in the mixed state observed in Nb-Ta and Pb-In sheets are discussed. The theoretical predictions that there will be a superconducting sheath near the sample surface for $H_{c2} < H < H_{c3} = 1.695\,H_{c2}$ for H parallel to the surface and no remanent conductivity beyond H_{c2} when H is perpendicular to the surface have been experimentally verified. When the surface of the superconductor was coated with a normal metal (copper), H_{c2} was not affected, but H_{c3} was reduced significantly. The effect of defects on H_{c2} and H_{c3} was studied. Defects in general do not affect H_{c2}, but as the amount of defects increases H_{c3} tends to shift toward higher fields and the distinction between the parallel and perpendicular field orientations becomes less significant.

24,018 CRITICAL TRANSPORT CURRENT BEHAVIOUR IN A SEMI-REVERSIBLE TYPE II SUPERCONDUCTOR by M.A.R. Leblanc (Aerospace and U. Southern California); Phys. Lett., Neth., Vol. 8, pp. 226-227(L), Feb. 15, 1964

Measurements of the critical transport current behavior in niobium wires are reported. Two different critical current curves were observed in a given longitudinal magnetic field, depending on the direction of current flow. The curves exchanged position when the polarity of the field was reversed. These results are attributed to a helical configuration of dislocations and grain boundaries induced in the wire in the course of mounting it. In a transverse field the critical current depends on the polarity of the current and on the direction of the transverse field in the plane perpendicular to the axis of the wire. The transverse field critical current curves also exchange position on reversal of the field direction. It is suggested that the upper critical field H_U in type II superconductors can be determined from the abrupt decrease of I_c in a longitudinal field. The measured critical current in a transverse field is in good agreement with the currents predicted by the modified Silsbee rule.

24,019 FOUR CRITICAL FIELDS IN SUPERCONDUCTING INDIUM LEAD ALLOYS by S. Gygax and J.L. Olsen (Swiss Fed. Inst. Tech.) and R.H. Kropschot (NBS); Phys. Lett., Neth., Vol. 8, pp. 228-230(L), Feb. 15, 1964

Experimental confirmation of the existence of superconductivity in polycrystalline indium lead alloys at a magnetic field H_{c3}, higher than the Ginzburg-Landau upper critical field H_{c2}, is reported. In an In + 6% Pb alloy, resistance first appeared for high currents at a field on the order of H_c; and at low currents, the resistance remains zero even in fields greater than H_{c2}. All curves tend to the normal resistance at a single, clearly defined field H'_{c3}. The temperature and concentration dependences of the four critical fields were measured. After annealing at 110°C for 60 hours H'_{c3} decreased to within 10 per cent of the theoretical value H_{c3}. Although it is not definately known that H'_{c3} corresponds to the H_{c3} given by the theory, the fact that H'_{c3} tends to zero at the transition temperature where H_{c1}, H_c and H_{c2} tend to zero indicates that H'_{c3} is a property of the alloy itself.

24,020 EXPERIMENTAL EVIDENCE FOR A NEW SUPERCONDUCTING PHASE NUCLEATION FIELD IN TYPE-II SUPERCONDUCTORS by W.J. Tomasch and A.S. Joseph (NA Aviation); Phys. Rev. Lett., Vol. 12, pp. 148-150(L), Feb. 10, 1964

Null-deflection torque magnetometer measurements of remanent superconductivity in thick films (4-10 μ) and bulk foils (51-127 μ) of Pb-Tl alloys containing 4.2-10.0 at.% Tl are discussed. The measurements were made over the temperature range 1.1-4.2°K and the field interval H_{c2} to 1.7 H_{c2}, where H_{c2} is the bulk upper critical field. Two critical fields H_l and H_t, which mark, respectively, the cessation of superconductivity with the field applied parallel and perpendicular to the plane of the specimen, were observed. Good agreement between H_{c2} and H_t was obtained. The ratio H_l/H_t was constant (1.69 ± 0.02), and independent of composition, thickness, and temperature. The observed values of H_l/H_t are in very good agreement with the theoretical values for H_{c3}/H_{c2} calculated by Saint-James and de Gennes. The experimental results suggest that $H_l = H_{c3}$ and $H_t = H_{c2}$, and that there is a superconducting sheath in the region $H_{c2} < H < 1.692\,H_{c2}$.

24,021 SUPERCONDUCTING BEHAVIOR OF PRESSURE INDUCED ZIRCONIUM POLYMORPH by B. Tittmann, D. Hamilton and A. Jayaraman (U. Calif.); J. Appl. Phys., Vol. 35, pp. 732-733, Mar. 1964

Superconducting transition behavior for α-Zr and ω-Zr is detailed. The transition temperature T_c of the α-Zr was 0.70° to 0.73°K, while that of the ω-Zr was 0.55°K to 0.65°K. The ω phase has a slightly greater density than α-Zr and the decrease in T_c with increase in density seems consistent with similar observations on mercury polymorphs.

24,022 EFFECT OF PRESSURE ON THE SUPERCONDUCTING TRANSITION TEMPERATURE OF THE ALLOYS Nb_3Sn AND Nb-Zr by E.S. Itskevich, M.A. Il'ina and V.A. Sukhoparov (Acad. Sci. USSR); Soviet Phys.-JETP, Vol. 18, pp. 949-950, Apr. 1964

The effect of isotropic compression p upon the superconducting transition temperature T_c for the alloys Nb_3Sn and Nb-Zr has been investigated. It is found that beginning at a pressure of ~3000 atm., the curve relating T_c and p for Nb_3Sn is quadratic in character and for Nb-Zr alloys, T_c increases upon application of pressure.

24,023 THE SURFACE IMPEDANCE OF SUPERCONDUCTORS by J.R. Waldram (Cavendish Lab.); Phil. Mag., Vol. 13, No. 49, pp. 1-88, 1964

Measurements of the surface impedance of superconducting tin and tin-indium alloys at 3 kMc are reported. At the lowest temperatures the penetration depth, λ, shows slight downward curvature when plotted against $y(T/T_c) = (1-(T/T_c)^4)^{-\frac{1}{2}}$ for $y < 1.2$, in contrast to the larger effect predicted by the theory. At higher temperatures the theory overestimates λ by about 5×10^{-7} cm. For samples containing more than 2 per cent indium λ(y) appears to be linear at all temperatures. The slope, dλ/dy, agrees with the predicted values for large y. The low temperature surface resistance follows the usual empirical rule

$$R_S/R_N = A(\omega)t^4(1-t^2)(1-t^4)^2,$$

with A(ω) only weakly dependent on purity. A method of obtaining λ at absolute zero, free from zero error, by analysis of the resistance and reactance data together is presented. The extension of the theory to anisotropic metals is applied to the results for pure specimens. A new method of measuring anisotropy of the energy gap is proposed. The simple relations between the Pippard parameters, G_1 and G_2, and the normal state skin depth discovered by Pippard and Fawcett is shown to be essentially accidental. In considering the surface impedance of pure specimens very near T_c, it is shown that the coherence length is certainly finite at T_c in tin, and a new interpretation is given for the results of Williams on pure aluminum near T_c.

24,024 MICROWAVE MAGNETOIMPEDANCE OF SUPERCONDUCTING TIN by R.T. Lewis (U. California, Berkeley); Phys. Rev., Vol. 134A, pp. A1-9, Apr. 61, 1964

Measurements of the temperature and magnetic field dependence of the surface impedance of a single crystal of superconducting tin at a frequency of 23.5 Gc are reported. The temperature dependence of the reactance in zero field agrees well with that calculated by Miller from the BCS theory. A small unexpected knee in the temperature dependence of the resistance is observed, centered around a reduced temperature of $t = 0.88$. This knee may arise from a band of p electrons with a smaller energy gap whose temperature dependence differs markedly from the BCS form. The change of surface resistance with applied field is found to be negative in the temperature range of the knee with the greatest negative dependence occurring at the center of the knee. The change of resistance is found to be positive outside this temperature range. The change of reactance with field is found to be positive. The association of the negative field dependence of the surface impedance with a band of p electrons is shown to give a qualitative explanation of the field dependence as observed in this and other investigations.

24,025 IMAGE PROPERTIES OF A SUPERCONDUCTING GROUND PLANE by A.R. Sass (Lewis Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 516-521, Mar. 1964

The Green's-function technique is utilized in the determination of the field distribution of an infinitely long current carrying conductor of arbitrary but constant cross section above a superconducting ground plane of finite thickness. It is assumed that the superconductor can be described by the phenomenological London equations. The integral expressions that are obtained are solved analytically for a few special cases of interest. Under conditions that are often en-

countered in a physical system, a modified image method can be utilized in order to calculate the field distribution to within 2 per cent of the computer solution.

24,026 THEORY OF QUANTIZATION OF MAGNETIC FLUX IN SUPERCONDUCTORS by L.P. Rapoport (Voronezh State U.); Soviet Phys.-JETP, Vol.18, pp. 1003-1005, Apr. 1964

A microscopic theory of quantization of magnetic flux in a superconducting cylinder is developed. The relation between this phenomenon and quantum vortices in a fermion system is indicated, and corrections to the magnitude of the quantum due to the size of the apparatus and the magnitude of the energy gap are obtained. It is shown that the discovery of the quantization of the magnetic flux is equivalent to a proof of the presence of quantum vortices in superconductors.

24,027 STRUCTURE OF FLUX JUMPS IN A HARD SUPERCONDUCTOR by M. A.R. LeBlanc and F.L. Vernon, Jr. (Aerospace Corp.); Bull. Am. Phys. Soc., Vol.9, p. 251(A), Mar. 1964

Observations are presented on flux jumps in a noninductively, close-wound, single-layer coil of Formvar insulated, severely cold-worked, 10-mil-diameter NbZr (25%) wire. Measurements indicate that a resistivity $\approx 10^{-7}\Omega \cdot$cm appears at the plateau of the flux jump that is independent of J, the transport-current density. The duration of the flux jumps is constant and ≈ 2 msec in this specimen. The flux jumps terminate in a catastrophic resistive transition when $J > 6 \times 10^4$ A/cm^2, and peak in ≈ 50 μsec. The structure of catastrophic and noncatastrophic flux jumps is extremely complicated and is described and discussed in terms of the Bean and Anderson models.

24,028 MAGNETIC BEHAVIOR IN SUPERCONDUCTION Nb-Zr WIRE by K. Yasukochi, T. Ogasahara and N. Usui (Nohon U., Tokyo) and S. Ushio (Oki Electric Co., Tokyo); J. Phys. Soc. Japan, Vol. 19, pp. 137-138(L), Jan. 1964

The magnetization of Nb-Zr (25%) wire in a transverse field is reported. Curves of magnetization versus external field and remanence versus maximum applied field are presented. It is felt that the residual field is attributable to the remanence in the wire. Measurements were also made of magnetization with bulk transport current in the Nb-Zr wire by the same method. Results appear to indicate that transport current sweeps away the induced magnetic moment.

24,029 DYNAMIC SUSCEPTIBILITY OF TYPE II SUPERCONDUCTORS by P. S. Swartz and H.R. Hart, Jr. (GE); Bull. Am. Phys. Soc., Vol.9, p. 252(A), Mar. 1964

The real component of the ac or dynamic susceptibility has been measured as a function of dc magnetic field H_{dc} for several Type II superconductors, using the frequency-shift technique of Schawlow and Devlin. Superconductivity in Nb-Ta ribbons extends beyond the Abrikosov upper critical field H_{c2}[2] to an experimentally well-defined field H_{c3}. H_{c3} appears to be a property of the composition of the material but is strongly dependent on the angle between H_{dc} and the surface plane of the specimen. Results to date are in excellent agreement with the superconducting-surface-film theory of Saint-James and de Gennes (to be published). They predict that $H_{c3} = 1.69\ H_{c2}$ when H_{dc} is parallel to the surface plane, and that the surface film disappears ($H_{c3} = H_{c2}$) when H_{dc} is perpendicular to the surface plane.

Infrared Absorption in La Superconductors - See 24,351

Photocurrents in Superconductors - See 24,407

Ultrasonic Attenuation in Superconductors - See 24,541

24,030 ULTRASONIC MEASUREMENTS IN NORMAL AND SUPERCONDUCTING NIOBIUM by R. Weber (Lincoln Lab.); Phys. Rev., Vol. 133A, pp.A1487-1492, Mar. 16, 1964

Phonon attenuation versus temperature measurements have been made on single-crystal niobium from 1.3 to 10°K for longitudinal phonon frequencies of 30 and 220 Mc/sec using the echo technique. In additon, the frequency dependence of the normal attenuation at 1.42°K has been determined from 30 Mc/sec to approximately 450 Mc/sec. Finally, time-of-flight shear and longitudinal measurements have been made at 4.2°K and 30 Mc/sec. It has been calculated that: the superconducting energy gap is $(3.63 \pm 0.06)kT_c$ for sound propagation along the [100], [110], and [111] axes; the normalized gap varies more strongly with the reduced temperature near T_c than is predicted by the BCS theory; the Debye temperature at 4.2°K is (271 ± 5)°K, as calculated from the computed elastic constants; and that the ratio of superconducting-to-normal attenuation falls below the value predicted by BCS as the temperature is increased towards T_c for the 30-Mc/sec phonons. The attenuation varied as the square of the frequency below 110 Mc/sec, while for the higher frequencies the dependence on frequency decreased. Thus, at 220 Mc/sec, $ql \sim 1$. A typical acceptable sample was at least 99.8% pure and had $T_c = (9.15 \pm 0.02)$°K. Other typical values were a resistivity ratio of 520 ± 50 and upper critical magnetic fields of 1710 ± 20 oe and 2020 ± 20 oe at 4.2 and 1.4°K, respectively.

24,031 SUPERCONDUCTIVITY IN INDIUM ANTIMONIDE by T.F. Strombe and C.A. Swenson (Iowa State U.); Phys. Rev., Vol. 134A, pp. A21-23, Apr 6, 1964

Two samples of the metallic phase of indium antimonide were stabilized at atmospheric pressure by cooling semiconductor grade material from 100°C to 77° at a pressure of 27 kbars, and then removing the pressure. Measurements of the magnetic moment of these samples down to 1.1°K were made using a sample-motion technique in a uniform magnetic field. Below 1.89°K, the samples exhibited bulk superconducting properties, in agreement with previous work. A high-field tail on the magnetization curves and the existence of considerable locked-in flux as the magnetic field was reduced were taken to be indications of a high state of residual strain in the sample. The slope of the critical field curve at 1.89°K was found to be $(\partial H_c/\partial T)_{T_c} = -103$G/°K. This is consistent with values found for soft superconductors with similar transition temperatures and implies a normal state electronic specific heat per cm^3, which is roughly half that of white tin. White tin has the same average ionic mass as metallic indium antimonide, and presumably the same electronic density.

24,032 SUPERCONDUCTIVITY IN GERMANIUM TELLURIDE by R.A. Hein, J.W. Gibson (U.S. Naval Res. Lab.), R. Mazelsky, R.C. Miller and J.K. Hulm (Westinghouse); Bull. Am. Phys. Soc., Vol.9, p. 268(A), Mar. 1964

The occurrence of superconductivity below 1°K in the compound germanium telluride has been confirmed in experiments on a large number of samples of various compositions prepared either by melting and casting or by sintering pressed powders. The transition temperature of these samples varied from 0.25 down to below 0.02°K, depending upon the starting composition and method of preparation. The compound germanium telluride forms with several per cent tellurium in excess of the formula GeTe. This results in a p-type material with a very high carrier concentration, around 10^{21} holes per cc. By raising the tellurium content, the hole concentration can be increased from about 0.7×10^{21} to about 1.5×10^{21} cm^{-3}, although the precise minimum and maximum self-doping concentrations have not yet been established. In the experiments, compositions with free germanium present (low hole concentrations) remained normal down to about 20 mdeg. Compositions with free tellurium present (high hole concentrations) became superconducting at about 0.25°K. Single-phase material with the formula $GeTe_{1.025}$ usually transited at about 0.08°K. These preliminary data suggest that T_c is a rapidly varying function of carrier concentration.

24,033 PROPERTIES OF Nb-Zr SUPERCONDUCTING WIRE by T.T.J. Hollerman (Westinghouse); Electronic Prod., Vol. 6, pp. 22, 85, Feb. 1964

A report on the magnetic and superconducting properties of Nb-Zr is given. Nb-Zr offers superior ductility enabling coil winding by conventional techniques. It does not require heat treatment or special processing. It is capable of supporting magnetic fields up to 90 kilogauss. The material's I_c vs H characteristics depend upon its geometry. A jig for measuring the shortlength parameters is described.

Superconductive (Ce-Cd) Ru - See 24,124

BREAKDOWN

Breakdown in:
$BaTiO_3$ - See 23,893
$BaZrO_3$ - See 23,995

MAGNETOELECTRIC (GALVANOMAGNETIC) PROPERTIES

GENERAL

24,034 SOME GALVANOMAGNETIC AND OPTICAL PROPERTIES OF Cu DOPED InSb FILMS by R.F. Potter and H.H. Wieder (U.S. Naval Ord. Lab.); Solid-State Electronics, Vol. 7, pp. 253-258, Apr. 1964

InSb layers have been prepared by the "three temperature" evaporation technique, and their galvanomagnetic and optical properties have been measured over a range of temperatures. The layers exhibited typical p-type characteristics with hole concentrations in the order of 10^{17}/cm^3 and electron/hole mobility ratios of approximately 32. Transmittance measurements were made for wavelengths between 2 and 40 microns for a range of sample temperatures. Changes in the refractive index may be determined from the behavior of the observed interference fringes. The lack of dispersion as well as the temperature dependence of the absorption is consistent with p-type behavior.

24,035 UNUSUAL GALVANOMAGNETIC PROPERTIES OF PYROLYTIC GRAPHITE by K. Takeya and K. Yazawa (U. Electro-Commun., Tokyo);

Phys. Soc. Japan, Vol. 19, pp. 138-139(L), Jan. 1964

ree unusual features observed in galvanometric behavior of "straight" and rogen-doped pyrolytic graphite are reported. These are: (1) negative resistce in n-type as well as p-type at 77°K; (2) field dependence of the negative gnetoresistance obeys the quadratic law and changes sign to positive in the gher field region; and (3) the Hall coefficient has opposite signs in the two ncipal axes.

,036 GALVANOMAGNETIC SIZE EFFECTS IN ALUMINUM FILMS by K. svoll and I. Holwech (U. Oslo, Norway); Phil. Mag., Vol.9, pp. 435-450, ar. 1964

e residual electrical conductivity of aluminum films has been measured in a nsverse magnetic field. The galvanomagnetic size effects were found to be good qualitative agreement with the theories of Sondheimer and of Macnald and Sarginson.

MAGNETORESISTIVITY

,037 HIGH FIELD MAGNETORESISTANCE OF INHOMOGENEOUS SEMIONDUCTORS AND PLASMAS — THE STRATIFIED MEDIUM by H.L. Frisch d J.A. Morrison (Bell Labs.); Annals Phys., Vol. 26, pp. 181-221, Feb. 1964

e steady state distribution of electrons in a high temperature, spatially inmogeneous semiconductor in a large magnetic field and infinitesimal electric ld is described using a theoretical, classical mechanics treatment.

gnetoresistivity of:
CrI_2 - See 24,083
Rh-Fe - See 23,969

cillatory Magnetoresistivity of Graphite - See 23,847

,038 MAGNETO-CONCENTRATION EFFECT IN SEMICONDUCTORS by M. Gershenzon, Yu.A. Gurvich and L.B. Litvac-Gorskaya (Lenin State dag. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1165-1168, Dec. 1963

e change in resistance of a semiconductor slab due to the magnetoconcentran effect is calculated. It is assumed that the opposite side faces of the slab ssess considerably different rates of surface recombination. The results calated are in qualitative agreement with experiment.

,039 NEW APPROACH TO DEHAAS/SCHUBNIKOV-EFFECT MEASURENTS by R.D. Brown (IBM Watson Lab.); Bull. Am. Phys. Soc., Vol.9, p. 4(A), Mar. 1964

a large amount of data reduction prior to recording, improvements in both e accuracy and sensitivity of the measurement of the periods of magnetoistance oscillations have been achieved. The monotonic ^2H term is subtract by bucking the signal against that of a similar sample kept at 77°K in the ne magnetic field; a field sweep that varies 1/H linearly in time allows the e of real-time differentiation and low-frequency filtering to isolate a particr frequency. The resulting sinusoidal plots allow direct and accurate deterination of the periods. These techniques have proved to be particularly use- (1) when beating periods occur and (2) for measuring small-amplitude, highquency oscillations. Preliminary results have been obtained on a bismuth gle crystal at ~1.6°K with the magnetic field in the xy plane. Both the ge- and small-electron periods in the binary direction (7.1 and 0.50×10^{-5} g^{-1}) and the two in the bisectrix direction (8.2 and 4.1×10^{-5} g^{-1}) were meased. These data, with the well-established value for the electron period in the gonal direction (1.19×10^{-5} g^{-1}) and Kao's value for the tilt angle (6°) give electron density per ellipsoid n of 0.96×10^{17} cm^{-3}. This result, which asnes the Fermi surface to be ellipsoidal, is the first value of n that is not afcted by nonparabolicity of the band.

,040 SHUBNIKOV-DEHAAS EFFECT IN PbS by M.R. Ellett and K.F. Cuff ockheed Res. Lab.); Bull. Am. Phys. Soc., Vol.9, p. 293(A), Mar. 1964

ubnikov-deHaas measurements have been carried out in n- and p-type single ystals of PbS in magnetic fields up to 26 kg at 4.2° and 1.1°K. The observed cillations indicate <111> ellipsoidal symmetry for both the valence- and conction-band extrema. The ellipsoid cross sections, observed as a function of agnetic-field orientation, indicate mass anisotropies ≤ 1.5 for both bands. alues of the cyclotron mass, determined for the magnetic field along the 00> axis (where single-period oscillations were observed) are 0.09 ± 0.01 d $0.105 \pm 0.01 m_0$ for the conduction and valence bands, respectively. Comrison of the measured cross sections with the total carrier density indicate at all carriers are accounted for in four ellipsoids, thus placing the extrema both bands at the Brillouin-zone face. A similar conclusion was reached for e conduction band by Allgaier et al. In light of the recent results on PbSe, now appears that the conduction- and valence-band extrema of PbS, PbSe, d PbTe all occur at the <111> Brillouin-zone face, and furthermore, the nd parameters vary in a systematic manner.

24,041 SHUBNIKOV-DEHAAS EFFECTS ON BISMUTH AT VERY LOW TEMPERATURES by M. Suzuki and S. Kikuchi (Sony Corp., Japan); J. Phys. Soc. Japan, Vol. 19, p. 134(L), Jan. 1964

Shubnikov-deHaas effects in Bi crystals have been measured at about 0.5°K using a He cryostat. With the magnetic field parallel to the X or Y axis, a short period of oscillation was found which is thought to be due to the hole band. With the field parallel to the Z axis, dips in the oscillation curve split into two and are considered to be due to spin splitting of the hole band.

24,042 THREE-FOLD SYMMETRY OF MAGNETORESISTANCE IN TIN-DOPED BISMUTH by T. Morimoto, J. Takamura and Y. Sugimoto (Kyoto U.); J. Phys. Soc. Japan, Vol.19, pp. 241-242(L), Feb. 1964

The configuration of light hole ellipsoids in k-space has been determined from measurements of the angular dependence of magnetoresistance in Bi polycrystals doped with 0.2 at.% Sn. From the 60° symmetry observed, one heavy hole ellipsoid and three light hole ellipsoids are considered as better models for the material than a previous one involving one light hole ellipsoid.

24,043 SELF-MAGNETORESISTANCE EFFECT IN BISMUTH by S. Tosima and R. Hirota (Lab. RCA, Tokyo); J. Phys. Soc. Japan, Vol.19, pp. 468-471, Apr. 1964

The self-magnetoresistance of Bi has been calculated for the pre-pinch regime, based on the energy band model proposed by Abeles and Meiboom. The inward-driven electron-hole flow contributes to departures from Ohm's law in the following ways: (a) particle flow due to the Lorentz force of the self-magnetic field gives a pure self-magnetoresistance effect, which decreases the conductivity; (b) if the life time of the electron-hole pairs is not too short, this particle flow distorts the carrier density distribution, creating a diffusion force which opposes the Lorentz force; this effect partially compensates the pure self-magnetoresistance effect, (c) if the surface recombination velocity is not zero, the particle flow increases the carrier density, so that the conductivity is increased.

24,044 NEGATIVE MAGNETORESISTANCE IN GERMANIUM STRONGLY DOPED WITH ANTIMONY by M. Mirzabaev, V.M. Tuchkevich and Yu.V. Shmartsev (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1179-1182, Dec. 1963

Resistivity, Hall coefficient and magnetoresistance have been measured between 1.7 and 290°K in five samples of n-type germanium doped with antimony at concentrations of 10^{17} to 2×10^{18} cm^{-3}. All samples exhibited negative magnetoresistance at temperatures corresponding to conduction in the impurity band. It is suggested that for samples with impurity concentration less than 5×10^{17} cm^{-3}, the reduction of the resistivity is related to a change in the carrier distribution in two bands of different mobility. For samples with impurity concentration higher than 5×10^{17} cm^{-3}, the reduction of the resistivity is related to a change in the efficiency of scattering under the action of a magnetic field.

24,045 ELECTRICAL PROPERTIES OF BISMUTH-ANTIMONY ALLOYS by G. A. Ivanov and A.M. Popov (Gertsen State Pedag. Inst.); Soviet Phys.-Solid State, Vol.5, pp. 1754-1761, Mar. 1964

Measurements of the tensor of the Hall coefficient, three components of the magnetoresistivity tensor $\rho_{11,11}$, $\rho_{11,22}$, $\rho_{11,33}$, and the resistivity perpendicular to the trigonal axis in the temperature range 77-300°K are reported. It is found that the Hall coefficient for all samples is negative throughout the entire temperature interval. The current carrier concentration and the zone overlap are estimated. The solid solutions of the Bi-Sb system, having high bismuth content but with antimony concentrations over 5 at.% are semiconductors at temperatures below 173°K.

24,046 SIZE EFFECT IN POLYCRYSTALLINE INDIUM PLATES IN A MAGNETIC FIELD by P. Cotti and J. Olsen (Swiss Fed. Inst. Tech.) and J. Daunt and M. Kreitman (Ohio State U.); Cryogenics, Vol.4, pp. 45-46(L), Feb. 1964

The effect of sample size on the magnetoresistivity of thin In plates has been studied. Experimental results agree with a one free electron per atom model. Theoretically, in the absence of a magnetic field, the resistivity of a thin plate contains a term due to electron scattering at the surface; applying a magnetic field causes the electrons to move in helical orbits with axes parallel to the field. Large fields will prevent some of the electrons from reaching the surface, reducing surface scattering, and the resistivity tends to that of bulk material. Experimentally, for perpendicular fields, an increase in resistivity was noted; for parallel fields, resistivity reaches a peak and then falls off.

24,047 MAGNETORESISTANCE OF THE CORBINO DISK AT MICROWAVE FREQUENCIES by C.B. Burckhardt (Swiss Fed. Inst. Tech.) and M.J.O. Sturtt (GE); Proc. IEEE, Vol. 52, pp. 277-283, Mar. 1964

The behavior of a Corbino disk of InSb in a static, transverse magnetic field and a high frequency electric field is investigated. Measurements and analysis show that, owing to an internal magnetic field effect, the impedance of the Corbino disk shows a frequency dependence even at microwave frequencies.

Measurements performed on rectangular samples show the same effect even more pronounced. It is concluded that, in the case of medium to high Hall angles, this effect may determine an upper frequency limit of Hall-effect devices which is considerably lower than the dielectric relaxation frequency.

24,048 OSCILLATORY MAGNETORESISTANCE OF GaSb by W.M. Becker and H.Y. Fan (Purdue U.); Bull. Am. Phys. Soc., Vol.9, p. 258(A), Mar.1964

Previously reported magnetoresistance oscillations in n-type GaSb measured with dc fields up to 30 kg have been studied, using pulse fields up to 150 kg. In a sample with $n = 1.25 \times 10^{18}$ cm^{-3}, over 20 oscillations of longitudinal magnetoresistance were observed, periodic in H^{-1}. From the field dependence of oscillation amplitude, a collision frequency was estimated that agreed with that given by Hall mobility. Using this estimate, the amplitude of oscillations was found to agree reasonably with the theory for single-band conduction. According to previous work, the oscillation amplitude appeared to be very sensitive to n, becoming undetectable for samples with $n \lesssim 10^{18}$ cm^{-3}. This is not consistent with theoretical estimates of collision frequency given when Hall mobility is used.

24,049 VALENCE-BAND STRUCTURE OF $PtSb_2$ by D.H. Damon, A. Sagar, and R.C. Miller (Westinghouse); Bull. Am. Phys. Soc., Vol.9, p. 217(A), Mar. 1964

The low-field magnetoresistance of five single-crystal samples of $PtSb_2$ has been measured at 77.3°K. All the samples had approximately the same extrinsic hole concentrations, $\sim 3 \times 10^{18}$ cm^{-3}. The magnetoresistance ratio $\Delta\rho/\rho_0$ was found to be proportional to the square of the magnetic-field strength H for $H \leq 11$ kg. The longitudinal magnetoresistance for two samples with the current in a 100 direction was found to vanish. The dependence of $\Delta\rho/\rho_0$ on the angles between the crystallographic axes and the current and magnetic field may be represented by a formula with four constants, b,c,d, and e (for crystals of class T_h, another term, proportional to e, must be added to the Pearson and Suhl formula). The best values of b, c, d, and e deduced from these measurements are 1.7, 0.5, -2.2, and 0.3×10^{-11} G^{-2}, respectively. These results show that the valence band has 100 symmetry. They may be fit to a simple many-valley model. The measurements of the piezoresistance at 77.3°K also show the 100 symmetry of the valence band.

Magnetoresistivity of ZnSb - See 23,939

Magnetoconductivity of Organic Semiconductors - See 23,938

HALL EFFECT

24,050 THEORY OF THE HALL EFFECT IN LOW-MOBILITY SEMICONDUCTORS by Yu.A. Firsov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol.5, pp. 1566-1580, Feb. 1964

Using Kubo's equation, the nondiagonal components of the conductivity tensor are divided into two parts. The first includes contributions from jump processes whereas the second is concerned with processes capable of being described by the transport equations. The equations are solved for temperatures $T < T_0$ where T_0 is a temperature close to the temperature of the minimum in the drift mobility. It is shown that in the region $T < T_0$, the Hall mobility increases with temperature as $\exp(E_a/kT)$, and has a maximum in the vicinity of T_0.

24,051 IN-PILE HALL ELECTRON TRANSPORT PROPERTY MEASUREMENTS ON ZONE-REFINED, P-TYPE SILICON by G.C. Bailey and C.M. Williams (Naval Res. Lab.); ONR Solution to Navy Probl. through Advanced Tech., 1963, pp. 246-262; STAR, Vol. 2, p. 916(A), Apr.8, 1964
ONR-16, Vol.1, OTS $5.00

The experiments discussed represent the first measurements of the Hall coefficient of silicon to be made in-pile, i.e., during neutron irradiation. In contrast to most of the previous investigations that were carried out on pulled silicon having about 10^{18} oxygen atoms/cm^3, the present experiments were made on zone-refined silicon containing less than 10^{16} oxygen atoms/cm^3.

24,052 HALL COEFFICIENT AND CONDUCTIVITY IN BISMUTH TELLURIDE by C.H. Champness and A.L. Kipling (Noranda Res. Ctr., Montreal); Bull. Am. Phys. Soc., Vol.9, p. 279(A), Mar. 1964

Investigations of the Hall coefficient, conductivity, and Seebeck coefficient from 77° to 500°K have been made on p- and n-type samples of bismuth telluride containing various excesses of tellurium. The conductivity measurements were made using ac techniques. As the Te concentration was increased, the conductivity and the electron concentration increased, changing the material from p- to n-type between 61 and 62 at.% Te. Above room temperature, the Hall mobility in n-type samples appeared to increase with Te content. At lower temperature, an approximately $T^{-1.4}$ dependence was found for the Hall mobility, indicating apparently that acoustic lattice scattering was dominant. The absence of an impurity activation energy was shown by the constant Hall coefficient at low temperatures. At higher temperatures, the slope of the $\log \sigma - 1/T$ plot for a p-type sample gave an activation energy of about 0.16 ev, while the corresponding slope of the $\log R_H - 1/T$ plot gave a larger valu

24,053 HALL EFFECT IN INDIUM ANTIMONIDE IN HIGH-INTENSITY PULSED MAGNETIC FIELDS by Kh.I. Amirkhanov, R.I. Bashirov and Z.A. Ismailov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol.5, pp. 2071-2073, Apr. 1964

The Hall effect in InSb in magnetic fields up to 450 koe and in the temperatu range 20-300°K has been investigated. It is shown that the change of the forbidden gap width in the magnetic field can be related to the nonparabolic sha of the conduction band and the strong splitting of Landau levels in the magnet field.

24,054 HALL-MEASUREMENTS ON SLIGHTLY REDUCED RUTILE (TiO_2) by G.A. Acket and J. Volger (Rijksuniversiteit, Utrecht); Phys. Lett., Neth., Vol. 8, pp. 244-246(L), Feb. 15, 1964

The variation of Hall coefficient with temperature in high resistivity (10^2-2 x 10^3 ohm-cm at room temperature) rutile is discussed. At the higher resistivities where the activation energy at room temperature is the same as at low temperature, the Hall constant exhibits a much simpler behavior than near 10^2 ohm-cm. Negligible scattering by donors was observed. At higher donor concentrations the variation of the Hall coefficient with temperature cannot be described by one activation energy. The present results suggest that the complicated behavior of the Hall constant in highly-doped material results from interactions between donors.

24,055 HALL EFFECT OF THE SOLID SOLUTIONS OF TiC_xN_{1-x} AND $Ti_xV_{1-x}C$ by F. Itoh, T. Tsuchida and H. Takaki (U. Kyoto); J. Phys. Soc. Japan, Vol. 19, pp. 136-137(L), Jan. 1964

Hall coefficients have been measured in TiC_xN_{1-x} and $Ti_xV_{1-x}C$ to study carrier density. It was found that the number of conducting electrons of titanium is approximately one, and it was concluded that the structure of transition metal nitrides is similar to that of transition metal carbides. It was found from the smoothness of a plot of number of conduction electrons versus concentration that TiC_xN_{1-x} obeys the rigid band model but $Ti_xV_{1-x}C$ behaves in a more complicated manner.

Hall Coefficient of:
- $AuSb_2$ and Cu_2Sb - See 23,994
- Bi-Sb - See 24,045
- $CrSi_2$ - See 23,993
- Ge - See 23,965 and 24,044
- PbTe-SnTe - See 23,832
- $SrTiO_3$ - See 23,992
- ZnSb - See 23,939
- Organic Semiconductors - See 23,938

Grain Size Dependence of Hall Coefficient in Bi and Bi-Sb - See 23,981

Hall Effect in:
- GaAs - See 23,844 and 23,976
- NiO(Li) - See 23,941

CYCLOTRON RESONANCE

24,056 CYCLOTRON RESONANCE OF HOT ELECTRONS by Yu.A. Gurvich (Lenin Moscow State Pedag. Inst.); Soviet Phys.-Solid State, Vol.5, pp. 2039-2042, Apr. 1964

A distribution function of hot electrons at the cyclotron resonance is derived and absorption is calculated as a function of the frequency and intensity of the incident radiation. It is found that the half-width of the line is given by the equality $\Delta\omega\tau_c \approx 1.6$. Comparison with experiment is discussed.

24,057 CYCLOTRON RESONANCE LINE BROADENING DUE TO CARRIER-CARRIER INTERACTION IN GERMANIUM by H. Kawamura, H. Saji, M. Fukai, K. Sekido and I. Imai (U. Tokyo); J. Phys. Soc. Japan, Vol.19, pp. 288-296, Mar. 1964

The resonance line broadening due to carrier-carrier interaction in the cyclotron resonance spectrum in pure germanium has been investigated by increasing the density of photo-generated carriers up to 10^{14} cm^{-3}. Measuring temperature ranged from 1.6°K to 15°K. The carrier density was estimated by combining the plasma shift of resonance line with the area under the absorption curve. While at high temperature the increment of the line width is approximately proportional to the carrier density, it is proportional to the square root of the carrier density at low temperature. It was found that the behavior at high density was well interpreted by the term of the scattering process by another carrier obeying the Brooks-Herring formula with the use of reduced mass of two interacting carriers. On the other hand, the broadening at low temperature for low density is rather

nhomogeneous in the sense that the cyclotron frequency is randomly modulated y the Coulomb field due to another carrier.

4,058 CYCLOTRON RESONANCE IN CADMIUM SULFIDE by K. Sawamoto NTT); J. Phys. Soc. Japan, Vol.19, pp. 318-322, Mar. 1964

xperiments of cyclotron resonance have been carried out for the charge car- ers in cadmium sulfide single crystals. The samples were selected from cleav- d parts of high pure grade A and ultra high pure grade CdS crystals of Eagle icher Co. The absorption corresponding to effective masses $m^* = 0.17$ m and $m^* = 0.81$ m was observed by use of 6 mm wavelength microwaves at 1.7°K. he light mass may correspond to free electron and the heavy one to hole. /hen the sample was not in contact with liquid helium, the absorption peak ecame broader due to the increase of lattice temperature, and at 9°K, the bsorption decreased gradually with increasing magnetic field. These results ean that $\omega\tau$ becomes smaller than unity with increasing temperature.

4,059 DOPPLER-SHIFTER CYCLOTRON RESONANCE AND ALFVÉN WAVE AMPING IN BISMUTH by J. Kirsch (IBM Watson Lab.); Phys. Rev., Vol. 33A, pp. A1390-1398, Mar. 2, 1964

t large magnetic fields the transmission of microwaves through bismuth is es- ntially undamped and can be regarded as Alfvén waves in a solid-state plas- a. A large kink has been observed in the 9-Gc/sec microwave absorption of ismuth as a perpendicularly applied magnetic field was varied through 1500 G t 2°K with field parallel to the binary axis. The kink has been identified as a oppler-shifted cyclotron resonance whose position is approximately given by $= \omega_c - v_{0x}k_A$ where v_{0x} is the maximum Fermi velocity along the field and k_A is the wave number of the microwaves. The kink marks the onset of Alfvén ave behavior where the surface resistance is proportional to the magnetic field. calculation of the surface resistance yields a variation with field which shows oth the Doppler-shifted peak and the high-field linear region which can be xtrapolated back through the origin. The frequency dependence of the peak erived from this calculation has been verified experimentally. By tilting the ield slightly away from the perpendicular it was shown that the peak was a oppler shift in the cyclotron resonance of the holes rather than of the elec- rons. This experiment provides a very accurate measure of the ratio of the ermi velocity to the Alfvén velocity and, thus, knowing one, the other may e determined. The Alfvén velocity in the same crystals was independently easured using an interference technique. Oscillations with a constant period n 1/H were observed in the reflected power as the applied magnetic field was aried. From the period of oscillation and the thickness of the crystal, the vel- city was deduced.

4,060 CYCLOTRON RESONANCE WITH DISPERSIVE-SCATTERING MECH- NISMS by N.K. Hindley (U. Illinois); Bull. Am. Phys. Soc., Vol. 9, p.249 A), Mar. 1964

ecent observations of cyclotron resonance in CdTe show a lineshape different rom that predicted by assuming a constant relaxation time to describe the scat- ering. The theory has been extended, for isotropic band structures, to the case f an energy-dependent relaxation time $\tau(E)$. The Boltzmann equation has been olved and the results expressed in terms of a conductivity tensor. The compo- ent that gives the power absorption in a cyclotron-resonance experiment has een calculated numerically, assuming $\tau \propto E^p$, with $p = -1/2$, $1/2$, and $3/2$. Of these alternatives (including the simple theory with $p = 0$), which are ap- ropriate for various different scattering mechanisms, the calculation with $p = 3/2$ appears to give the best agreement with the experimental results. This dis- ersion law is characteristic of ionized-impurity scattering. Calculations of the ther components of the conductivity tensor have also been made. Various com- inations of these components enter into the expressions for the free-carrier Faraday rotation and other magneto-optical phenomena, and the present results are applicable to these effects.

ELECTRICAL PROPERTIES OF SURFACES

24,061 FIELD-ENHANCED SECONDARY ELECTRON EMISSION FROM FILMS OF LOW DENSITY by G.W. Goetze, A.H. Boerio and M. Green (Westing- house Res. Labs.); J. Appl. Phys., Vol. 35, pp. 482-489, Mar. 1964

Low-density deposits of KCl showing stable secondary electron gains of 30 to 60 in transmission have been prepared by evaporation in an argon atmosphere. The layers have a fast response, high resistivity, and long life under primary electron bombardment. Measurements of their electrical properties suggest that the emission current consists entirely of true secondary electrons and no ava- lanche multiplication processes occur in the region of stable operation. Practi- cal application of these layers as dynodes in electron multipliers and image in- tensifiers and as targets in camera tubes is discussed in some detail.

24,062 SECONDARY ELECTRON EMISSION OF KBr FILMS by M.V. Gomoy- unova (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1853-1857, Mar. 1964

Measurements of the effective depths of penetration of primaries and of emis- sion of secondaries for KBr films are reported. Typical data on the thickness dependences of the secondary electron emission coefficient σ and the inelastic electron reflection coefficient η are presented. It is found that for primary elec- tron energies $E_p < 1$ kev, the effective depth of emission of the true secondary electrons λ_{eff} is approximately equal to the depth of penetration of the primar- ies ℓ. In the range 1 kev $< E_p < 4$ kev, λ_{eff} continues to rise, but the rise lags considerably behind the rise of ℓ.

24,063 ENERGY DISTRIBUTION OF SECONDARY ELECTRONS AND PHOTO- ELECTRONS EXCITED BY SOFT X-RAYS by N.G. Nakhodkin and P.V. Mel'- nik (Kiev State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1779-1783, Mar. 1964

The spectra of secondary electrons and photoelectrons excited in evaporated films of Au, Ge and Cu by primary electrons and X-ray quanta having the same energy of about 1.5 kev are discussed. Analysis of the data demonstrates that slow electrons with energies of a few electron volts are predominant in both spectra. The number of Auger electrons present in the photoelectrons is greater than that present in the case of secondary emission.

24,064 ON THE EMISSION OF NONEQUILIBRIUM ELECTRONS FROM CAD- MIUM SULFIDE DURING ILLUMINATION by V.F. Bibik (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 950-954, Nov. 1963

The results of an experimental investigation show that the variation of the emis- sion of nonequilibrium electrons from CdS crystals is governed by variation of the field magnitude and the electron density in the active region. The effect of the field on the variation of the spectral composition of the light gives a natural explanation of the absence of correlation between the emission and photocon- ductivity currents. The rise of the photoconductivity and emission currents on illumination with short-wavelength light may be due to a reduction of the sur- face recombination of photocarriers in a strong field.

24,065 ENERGY DISTRIBUTION OF ELECTRONS IN FIELD EMISSION FROM GERMANIUM FILMS ON TUNGSTEN by N.V. Mileshkina and I.L. Sokol'- skaya (Leningrad State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1826-1832, Mar. 1964

The electron energy distribution has been measured for field emission from tung- sten covered with germanium films of atomic thickness. The distribution curves were found to have two maxima: one coinciding with the maximum for a pure emitter and the other displaced toward lower electron energies. The origin of the second maximum is related to the possible field emission from the valence band of the germanium film.

24,066 SECONDARY POSITIVE ION EMISSION FROM A TANTALUM SUR- FACE by J.A. McHugh and J.C. Sheffield (Knolls Atomic Power Lab.); J. Appl. Phys., Vol. 35, pp. 512-515, Mar. 1964

The secondary positive ions ejected from a tantalum target by a mass-analyzed primary beam were detected and studied in a mass spectrometer. The secondary ion emission consisted of species characteristic of the metal (Ta^+), metal com- pounds (oxides), and multiatomic ions of the metal (Ta_2^+, Ta_3^+). Reflection of normally incident gas ions from the Ta surface was not observed; the specular reflection coefficient of ions to ions is then less than 10^{-6}. The relative secon- dary ion yields for tantalum, measured for normally incident Hg^{202} ions at en- ergies between 0.3-14 kev, were independent of the incident ion charge. A dependence of the Ta^+ secondary yield on mass of the incident ion was observ- ed. The dependence of the secondary ion yield on mass and energy of the inci- dent ions was very similar to that observed for total sputtering yields.

24,067 WORK FUNCTION OF THE (110) FACE OF TANTALUM IN CESIUM VAPOR by W.T. Norris (MIT); J. Appl. Phys., Vol. 35, pp. 467-469, Mar. 1964

The effective work function of the (110) face of a crystal of tantalum in the presence of cesium was estimated from values of the saturated electron emission deduced from the characteristics of a diode. The temperature of the cesium res- ervoir ranged from 320° to 380°K and the emitter temperatures were in the range 1100° to 1350°K. Under these conditions the work function of the cesium-cov- ered surface was about 0.3 ev lower than that of polycrystalline material under similar conditions.

24,068 WORK FUNCTION IN THE SYSTEM THORIUM-RHENIUM by E.P. Gyftopoulos (MIT); J. Appl. Phys., Vol. 35, p. 464, Feb. 1964

The work function for a rhenium surface covered by thorium was found to be 3.15 ev. The results obtained by Gyftopoulos and Levine (J. Appl. Phys., Vol. 33, p. 67, 1962) are compared with those obtained by J. Anderson, W.E. Dan- forth and A.J. Williams, III (J. Appl. Phys., Vol. 34, p. 2260, 1963) and they are shown to be in agreement. The same work function is calculated theoretical- ly, giving 3.1 ev.

24,069 EQUALITY OF THE TEMPERATURE DEPENDENCE OF THE GOLD- SILICON SURFACE BARRIER AND THE SILICON ENERGY GAP IN Au n-Type

Si DIODES by C.R. Crowell and S.M. Sze (Bell Labs.) and W.G. Spitzer (U. Southern California); Appl. Phys. Lett., Vol. 4, pp. 91-92(L), Mar. 1, 1964

Photoelectric measurements of the barrier height variations of gold-n-type silicon Schottky barriers with temperature over the temperature range 106° to 363°K are reported. The experimental results indicate that the incremental change of the barrier height and the variation of the Si band gap with temperature are almost identical, and that the Fermi level at the Au-Si interface is pinned in relation to the valence band edge. For 0.2 and 8.2 ohm-cm silicon, the Fermi level is calculated to lie 0.305 ± 0.010 ev and 0.335 ± 0.010 ev above the valence band, respectively.

24,070 SURFACE PROPERTIES OF CdS SINGLE CRYSTALS by M. Itakura and H. Toyoda (NTT); Japanese J. Appl. Phys., Vol. 3, pp. 197-202, Apr. 1964

Properties of electrical contacts on cadmium sulfide single crystals have been studied. For a cleaved surface, the dc rectifying characteristics and the capacitance relations show the existence of a Schottky-type barrier. The differences from the properties of bulk crystals and the dispersion of surface admittance are considered to be due to the effect of multicontacts. For a polished surface, a small rectification ratio and high resistance suggest the existence of an insulating layer. The dependence of capacitance on biasing field also supports the model.

OTHER ELECTRICAL PROPERTIES

24,071 ACOUSTOELECTRIC EFFECT by S.G. Eckstein (Argonne Lab.); Bull. Am. Phys. Soc., Vol.9, p. 272(A), Mar. 1964

General expressions for the acoustoelectric current and fields were derived for metals, semiconductors, and semimetals in the presence of external electric and magnetic fields. In semiconductors with high deformation potentials or large piezoelectric coupling, the Weinreich relation is valid; however, in metals, collision-drag effects cause the acoustoelectric field to differ significantly from that predicted by the Weinreich relation. This is in disagreement with previous work by Mikoshiba and Spector. The Weinreich relation is not valid for semimetals. However, in high magnetic fields, the acoustoelectric current and field in semimetals are proportional to the attenuation. The acoustoelectric field is then in the direction q x H, where q is the wave vector and H the magnetic field. The acoustoelectric current reinforces the original dc under amplifying conditions. This is in agreement with the observations by Esaki of anomalous magnetoresistance in Bi.

24,072 ACOUSTOELECTRIC EFFECT IN n-TYPE Ge AND Si by V.D. Iskra (Chernovtsy State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1946-1953, Mar. 1964

The acoustoelectric effect in n-type Ge and Si is considered on the assumption that the frequency of the ultrasound is much less than the reciprocal of the electron relaxation time. The effect is investigated by the transport equation method, with allowance for intervalley transitions. The result shows that the value of the intervalley relaxation time determines the value of the electric field intensity characteristic of the acoustoelectric effect.

24,073 ELECTRON TUNNELING AND SCHOTTKY IONIZATION FROM EXCITED F CENTERS IN AN ELECTRIC FIELD by R.N. Euwema (Swarthmore Coll.) and R. Smoluchowski (Princeton U.); Phys. Rev., Vol. 133A, pp. A1724-1726, Mar. 16, 1964

It is known that an applied electric field can ionize an excited F center. Assuming a simple Coulomb field the probability of this process is calculated for tunneling and for Schottky ionization. The results compare satisfactorily with experiment and they lead to the possibility of an evaluation of the separation between the excited state of an F center and the conduction band adjusted to the excited state.

24,074 INFLUENCE OF WATER VAPOUR ON THE RECTIFYING AND ELECTROLUMINESCENT PROPERTIES OF ANODIC OXIDE FILMS ON ALUMINIUM by J. Wesolowski (Boleslaw Bierut U., Wroclaw), R. Dragon and J. Mochniak (Inst. Phys., Teachers' Coll., Opole); Acta Phys. Polonica, Vol. 24, pp. 407-414, Sept. 1963

The effect of water vapor on the electrical and electroluminescent properties of Al/Al_2O_3/solid counterelectrode systems was investigated experimentally. Electrical asymmetry and the anodic luminescence were found to occur only in the presence of water adsorbed into the oxide from the ambient medium. On the basis of the experimental observations the suggestion is made that the mechanism of rectification is associated with the process of electrolysis rather than with the p-n or p-i-n internal structure of the oxide.

Properties of Contacts to CdS - See 23,828

24,075 SOME ELECTRICAL PROPERTIES OF THE INTERMETALLIC COMPOUND ϵ-Zn_3Sb_2 by Ya.A. Ugai and E.M. Averbakh (Voronezh State U.); Soviet Phys.-Solid State, Vol. 5, pp. 940-941, Nov. 1963

Measurements of the temperature dependence of the conductivity and the differential thermoelectric power in the temperature range 20-470°C on polycrystalline samples of ϵ-Zn_3Sb_2 are reported. It is found that the low-temperature ϵ-phase is a p-type semiconductor with a forbidden bandwidth of 0.2 ev. From measurements of the Hall effect at room temperature the hole mobility was found to be 200 $cm^2/Vsec$. The observed discontinuities of the differential thermoelectric power at 405 and 437°C are explained by phase transitions of the intermetallic compound Zn_3Sb_2.

Electrical Properties of $(Ag_2Te)_{0.41}$-$(Sb_2Te_3)_{0.59}$ - See 23,781

MAGNETIC PROPERTIES

GENERAL

MAGNETIC SUSCEPTIBILITY

24,076 A JEWEL MOUNTED MICRO-BALANCE FOR THE MEASUREMENT MAGNETIC SUSCEPTIBILITIES OF CRYSTALS by D. Das (Indian Assoc. Cul vation of Sci., Calcutta); Indian J. Phys., Vol. 37, pp. 582-589, Nov. 196

A jewel-mounted microbalance has been designed and constructed for the mu urement of the magnetic susceptibilities of dia- and paramagnetic crystals at various temperatures. The balance is of robust and stable construction and it deflectional sensitivity is magnified very much by a suitable optical level ar rangement. The magnetic force upon a sample suspended by a thin fiber from one arm of the balance is compensated by the force exerted upon a small cu rent bearing coil by a permanent magnet. The sample, when in the form of c single crystal, is free to set with its maximum susceptibility in the horizonta plane along the direction of the magnetic field. When the balance is calibra ed by a standard sample, the above method gives directly the maximum susce tibility in the horizontal plane. The sensitivity of the compensation device i 1.65×10^{-6} gms per microampere of compensating current.

24,077 EXCHANGE COUPLING OF NEIGHBORING Mn^{++} IONS IN Mn^{++} ZnS CRYSTALS by W.H. Brumage, R. Yarger and C.C. Lin (U. Oklahoma); J. Appl. Phys., Vol. 35, pp. 994-995, Mar. 1964

The magnetic susceptibilities have been measured over the temperature range 20°-800°K for five ZnS crystals doped with Mn^{2+} in varying concentrations from 0.5% to 7.5%. Above 77°K the magnetic data show considerable deviation from Curie's law, which can be explained by the antiferromagnetic coupling between the Mn^{2+} ions situated at the nearest neighboring cation sites the ZnS crystal. To account for the experimental results quantitatively, it is assumed that the numbers of clusters of various types are determined by statistics of random distribution and that the exchange operator can be taken as th simple isotropic form $-2J(S_1 \cdot S_2)$. The observed susceptibilities can then be fi ted to the theoretical values using $J = -9 \pm 1\ cm^{-1}$. Additional terms of the exchange operator such as the next-nearest neighbor interaction, anisotropic exchange, and the biquadratic coupling terms are discussed.

24,078 SOME MAGNETIC PROPERTIES OF A GADOLINIUM SINGLE CRY TAL by V.I. Chechernikov, I. Pop, I.V. Burov, and E.M. Savitskii (Mosco State U.); Soviet Phys.-JETP, Vol. 18, pp. 595-597, Mar. 1964

The magnetic properties of a gadolinium single crystal have been investigate from 20 to 1000°C. It is found that the magnetic susceptibility measured in c direction perpendicular to the c axis is larger than that measured in the para lel direction. The existence of a critical field at 3000 oe was observed. The size of the magnetization jump decreases with increase of temperature and va ishes at T = 100°C. The results obtained show the presence in gadolinium of complicated spin configuration.

24,079 MAGNETIC PROPERTIES OF GADOLINIUM ORTHOPHOSPHATE ($GdPO_4$) by F.F.Y. Wang and R.S. Feigelson (Sperry Rand); Bull. Am. Phys. Soc., Vol.9, p. 226(A), Mar. 1964

The magnetic susceptibility of gadolinium orthophosphate ($GdPO_4$) was studi by the Faraday method from 20° to 700°K. At high temperatures, the suscept bilities follow the Curie-Weiss law, $\chi = C/T - \theta$, with the asymptotic Curie point (θ) extrapolated to be -170°K. The Néel point is found to be 225°K. Below the Néel point, it is antiferromagnetic. Its magnetizations were found to be strongly dependent on magnetic-field strengths. In the neighborhood of 20°-22°K, it undergoes a transition similar to those exhibited by terbium and dysprosium metals. This indicates that at lower temperatures $GdPO_4$ may be come ferromagnetic, and in the antiferromagnetic state (between 22° and 225 it may possess a spiral spin configuration.

4,080 MAGNETIC SUSCEPTIBILITIES OF Mo-Tc BINARY ALLOYS by D.J. am, D.O. Van Ostenburg and D.W. Pracht (Argonne Lab.); J. Appl. Phys., ol. 35, pp. 976-977, Mar. 1964

Magnetic susceptibilities of binary Mo-Tc alloys have been measured in the emperature range from 300°K to the superconducting transition temperature. he room-temperature magnetic susceptibility increases from pure Mo (82.5×10^{-6} emu/g-atom) to a small maximum (96.5×10^{-6} emu/g-atom) at the equitomic composition. Further additions of Tc produce a decrease which reaches minimum at 70 at.% Tc ($\chi = 87.3 \times 10^{-6}$ emu/g-atom). Beyond this composition there is another increase to the value of 120.8×10^{-6} emu/g-atom for he pure Tc. No Curie or Curie-Weiss type of temperature dependence of the usceptibility was observed in all the alloys in the temperature range investiated. The results are discussed in relation to the band theory of metals and ome generalizations about the d-band form of the three transition metal series aving the same electron concentrations are made.

4,081 MAGNETIC SUSCEPTIBILITY AND EXCHANGE COUPLING IN CdS OPED WITH MANGANESE by M.M. Kreitman (Aerospace Res. Lab.); Bull. m. Phys. Soc., Vol. 9, p. 225(A), Mar. 1964

Measurements carried out at liquid-helium temperatures on the magnetic susceptibility of a number of spherical CdS single crystals doped with manganese n amounts from 0.01% to 1.9% by weight have yielded data indicating (a) that he susceptibility is essentially isotropic and (b) an antiferromagnetic pairing ff of close neighbors observable at manganese concentrations above 0.2%. he data indicate that the exchange coupling between random isolated Mn^{2+} earest-neighbor pairs corresponds to a Néel temperature of about 6°K. Effects f exchange interaction between random Mn^{2+} pairs at greater distances apart predominantly next-nearest neighbors) are also evident clearly in the data, nd for these the coupling is also antiferromagnetic with an effective Néel temperature of about 0.9°K.

24,082 MAGNETIC SUSCEPTIBILITIES OF Ni^{2+} IN ZnO AND CdS CRYSTALS y W.H. Brumage and C.C. Lin (U. Oklahoma); Bull. Am. Phys. Soc., Vol.9, o. 244(A), Mar. 1964

The magnetic susceptibilities of Ni^{2+}-doped ZnO and CdS crystals have been measured at 30°-500°K. The susceptibilities for both crystals approach constant values at low temperature and decrease more rapidly with increasing temperature at $T > 60$°K. An unusually large magnetic anisotropy is observed for Ni^{2+}:ZnO. The non-Curie behavior can be explained on the basis that the ground tate of Ni^{2+} is nonmagnetic (A_1) and the temperature-dependent susceptibility arises mainly from the ions in the first two excited states (A_2 and E). By fitting he theoretical susceptibilities to the experimental values, the spin-orbit coupling constants and the trigonal splittings of the $T_1[^3T(F)]$ state have been determined. In both host crystals, the spin-orbit coupling constants are about half of the free-ion value.

Effect of Defects on Magnetic Susceptibility - See 24,259

24,083 DEPENDENCE OF THE ELECTRIC AND MAGNETIC PROPERTIES OF CHROMIUM IODIDE ON THE MAGNETIC FIELD STRENGTH AND TEMPERATURE by T.I. Kostina, T.N. Kozlova and E.I. Kondorskii (Moscow State U.); Soviet Phys.-JETP, Vol. 18, pp. 931-933, Apr. 1964

The dependence of the magnetic susceptibility and electric resistance of chromium iodide on the temperature and external magnetic field has been investigated. Two transition temperatures are observed at temperatures 150°K and 310°K. In the temperature range 150-310°K a critical field strength exists, for which the magnetization increases and the resistance decreases. The results can be explained by assuming that there exists in chromium a helicoidal structure in the temperature range 150-310°K.

24,084 MAGNETIC SUSCEPTIBILITIES OF SEVERAL SALTS AT LIQUID-He^3 TEMPERATURES by S.A. Friedberg and J.T. Schriempf (Carnegie Inst. Tech.); J. Appl. Phys., Vol. 35, pp. 1000-1001, Mar. 1964

The magnetic susceptibilities of several compounds have been measured between 0.35° and 4.2°K in a He^3 cryostat by an audiofrequency mutual-inductance technique. The powder susceptibility of $[Cr_3(CH_3COO)_6(OH)_2]\cdot 8H_2O$ obeys a Curie-Weiss law. Powder data show $Co(CH_3COO)_2\cdot 4H_2O$ and $Ni(CH_3COO)_2\cdot 4H_2O$ to be paramagnetic down to 0.35°K; the cobaltous salt does not exhibit the anomaly at 0.6°K inferred earlier from adiabatic demagnetization data. The powder susceptibility of $Mn(HCOO)_2\cdot 2H_2O$ departs from Curie-Weiss behavior at these temperatures due to exchange interaction among many of the Mn^{2+}'s. Powder and single-crystal data on $FeCl_2\cdot 4H_2O$ indicate antiferromagnetic behavior with a Néel point $T_N \sim 1$°K and preferred spin alignment along or near the monoclinic b axis. The susceptibilities above T_N have been analyzed in terms of the energy levels of a single Fe^{2+} ion and the large anisotropy given a reasonable interpretation.

24,085 MAGNETIC SUSCEPTIBILITY OF $FeCl_2\cdot 4H_2O$ BETWEEN 0.35° AND 4.2°K by J.T. Schriempf and S.A. Friedberg (Carnegie Inst. Tech.); Bull. Am. Phys. Soc., Vol. 9, p. 226(A), Mar. 1964

The single-crystal susceptibilities of monoclinic $FeCl_2\cdot 4H_2O$ have been determined by an audiofrequency method in a ^3He cryostat. The susceptibility along the diad axis χ_b exhibits a broad maximum of 1 cgs/mole near 1.5°K and is falling rapidly at 0.4°K where it equals 0.2 cgs/mole. χ_c is nearly constant at 0.3 cgs/mole. $\chi_{a'}$ (where $a' \perp$ b and c) reaches the maximum value 0.6 cgs/mole near 1.5°K and essentially coincides with χ_c below 0.7°K. Below ~ 1°K, this salt behaves antiferromagnetically with the preferred direction of spin alignment along or near the b axis. The large anisotropy of the susceptibilities above the Néel point, the specific heat in the same region, and the Curie-Weiss susceptibility observed above 14°K are explained by using a spin Hamiltonian with $S = 2$ for each Fe^{2+} ion and treating exchange interaction in a molecular-field approximation.

24,086 SUSCEPTIBILITY AND ANTIFERROMAGNETIC RESONANCE IN COBALTOUS OXIDE by M. Tachiki (Osaka U.); J. Phys. Soc. Japan, Vol. 19, pp. 454-460, Apr. 1964

The magnetic susceptibility and antiferromagnetic resonance of CoO have been studied on the basis of Kanamori's theory, in which the residual orbital angular momentum plays an important role in the magnetic properties of CoO. The parallel susceptibility does not vanish at 0°K due to the unquenched orbital angular momentum. The calculated parallel, perpendicular, and powder susceptibilities are in good agreement with measured values. The antiferromagnetic resonance modes and frequencies are calculated by the method of using fictitious magnetic fields. In the absence of an external field there are four modes, which are pair-wise degenerate. The frequencies obtained at 0°K are 5.76×10^{12} sec^{-1} and 16.61×10^{12} sec^{-1}, which correspond to far-infrared wavelengths of 52.0 microns and 18.1 microns, respectively.

Magnetic Susceptibility of:
$CoTiO_3$ - See 23,591
Orthoferrites - See 24,207
Rare Earth-NaMo Scheelites - See 23,801

24,087 CHANGES IN MAGNETIZATION OF SINGLE-CRYSTAL DYSPROSIUM, ERBIUM, AND HOLMIUM IN HIGH MAGNETIC FIELDS by R.B. Flippen (du Pont); J. Appl. Phys., Vol. 35, pp. 1047-1048, Mar. 1964

Measurements are reported on the behavior of magnetization with field of single-crystal dysprosium, erbium, and holmium in pulsed magnetic fields up to 165 koe. These elements go progressively, with decreasing temperature, from a paramagnetic to antiferromagnetic to ferromagnetic state. Sufficiently high external fields applied along spin axes in single-crystal samples can cause spin realignment by overcoming the internal exchange and anisotropy fields. The strengths of the internal fields can be determined in this manner. measurements with an external field H applied in the basal plane of Dy and of Ho, and with H parallel to the c axis in Er, confirm previous static field measurements of H_c for the AF/F transition. No change in spin alignment is seen in Dy with H parallel to c up to 165 koe. In Ho below 80°K, fields near 100 koe produce strong changes in magnetization with H parallel to the c axis. Below 20°K, fields up to 17 koe in the basal plane in Er produce a sharp change in magnetization indicative of spin realignment. The magnetization of Er with H parallel to a is measured at 4.2°K in static fields up to 56 koe. The magnetization increases sharply between 15 and 20 koe, reaching 50 emu/g at 20 koe. Little change is found above 40 koe where M is 120 emu/g. These results are discussed with regard to the internal fields in Dy, Ho, and Er.

Magnetic Properties of EuS - See 24,133

MAGNETIC STRUCTURE

24,088 COEXISTENCE OF MAGNETIC AND ELECTRIC ORDERING IN CRYSTALS by G.A. Smolenskii and V.A. Bokov (Acad. Sci. USSR); J. Appl. Phys., Vol. 35, pp. 915-918, Mar. 1964

Magnetic and electric properties of some single crystals of complex composition of perovskite-type structure were investigated and coexistence of ferroelectric and antiferromagnetic properties was shown in them. It was found that single crystals $YMnO_3$ and $YbMnO_3$ of the new class of ferroelectrics, discovered by Bertaut and others, are also antiferromagnetics. The results of the investigation of solid solutions based on $BiFeO_3$, which has a perovskite-type structure, are discussed. The opinion is expressed that $BiFeO_3$ is probably not a ferroelectric. The main results concerning the thermodynamic theory of substances which are ferroelectric and ferromagnetic simultaneously are given in this report.

24,089 APPLICATION OF THE GREEN'S FUNCTION METHOD TO THE ANALYSIS OF MAGNETIC LATTICES by A.G. Khachaturyan (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1586-1590, Feb. 1964

An analysis of a magnetic lattice having a spin of 1/2 on each lattice site is made. The spin interaction is described by an isotropic Heisenberg Hamiltonian.

A nonlinear equation for average magnetic moments is obtained by the method of Green's function. The dependence of the solution on the site coordinates gives the structure of the magnetic unit cell of the superlattice, and the dependence on the temperature describes the thermal evolution of magnetic lattices.

24,090 HIGHER-ORDER CORRECTIONS TO THE MOLECULAR-FIELD THEORY OF THE MAGNETIC STATE by G. Dresselhaus (Lincoln Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 291(A), Mar. 1964

A hierarchy of approximations is set forth in which the expectation value of the spin at the ith site in the nth approximation is given by $\langle S_i^z \rangle = \Sigma \langle S_i^z \rangle_j \epsilon^j$; the sum being taken j = 0,n. The coefficients $\langle S_i^z \rangle j$, are computed by equating terms in ϵ_j in the expression $\langle S_i^z \rangle = \mathrm{tr}[\exp(-\beta\mathcal{H}) S_i^z]/\mathrm{tr} \times \exp(-\beta\mathcal{H})$, in which $\epsilon\mathcal{H}' = +1 2\Sigma\, J_i | \langle S_i^z \rangle S_i^z + \mathcal{H}$, $\mathcal{H} = \mathcal{H}_0 + \epsilon\mathcal{H}'$, and $\mathcal{H}$ is the Heisenberg Hamiltonian. The 0th and and 1st approximations correspond to the Weiss molecular-field result. The high-temperature expansion of the nth approximation gives the susceptibility, $\chi^{(n)} = \chi_0 = (1 + \cdots + a_n/t^n)/(1 - a_1 a_n/t^{n+1})$, in which the a_i are the usual coefficients of the high-temperature susceptibility expansion, $t = kT/J$, and χ_0 is the paramagnetic result. The nth approximation to the Curie temperature is given by $(kT_c/J)^{n+1} = (a_1 a_n)$. The temperature dependence of the magnetization near T_c is also obtained.

24,091 INTERACTION BETWEEN LOCALIZED STATES IN METALS by S. Alexander (Weizmann Inst. Sci., Israel) and P.W. Anderson (Bell Labs.); Phys. Rev., Vol. 133A, pp. A1594-1603, Mar. 16, 1964

The theory of localized magnetic states of solute atoms in metals is extended to the case of a pair of neighboring magnetic atoms. It is found that the simplified model based on the idea that the important interaction is the diagonal exchange integral in the localized state, which is exactly soluble in Hartree-Fock theory for isolated ions, is still soluble, and the solutions show both ferromagnetic and antiferromagnetic exchange mechanisms.

24,092 SOME STRUCTURE-PROPERTY RELATIONSHIPS IN THIN MAGNETIC FILMS by K.Y. Ahn, G.S. Ansell, C.J. Barton and W.R. Beam (Rensselaer Polytech. Inst.); J. Appl. Phys., Vol. 35, pp. 1187-1190, Apr. 1964

When Permalloy films are annealed, the H_c and H_k of the as-deposited films are observed to decrease and α, the dispersion angle, is seen to increase. Electron diffraction studies show the development of long-range order in these films with annealing, as evidenced by the appearance of superlattice lines. The changes in H_k and α can be partly explained by this transition from short- to long-range order, and a model is proposed.

24,093 MAGNETIC PROPERTIES OF Eu by G.P. Arnold, C.E. Olsen and N.G. Nereson (Los Alamos Lab.); J. Appl. Phys., Vol. 35, p. 1031, Mar. 1964

Data which verify the transition of Eu to an antiferromagnetic state below 91°K which consists of a helical spin structure with the magnetic moments lying parallel to a cube face and with the screw axis directed perpendicular to the moments or along the [100] direction are presented. Information regarding the period of the helical structure was obtained from the separation of satellite reflections. The separation, which was observed to change very little with temperature, corresponds to a period of 3.5a at $T/T_N = 1$ and increases to 3.6a at $T/T_N = 0.05$, where a is the lattice spacing. The intense [000±1] magnetic reflection occurring at a scattering angle of 4.8° permits a calculation of the ordered magnetic moment in Eu. The experimental saturated ordered moment is $5.9 \pm 0.4\ \mu_B$. Assuming that the magnetic constituent of metallic Eu is a Eu^{2+} ion and is, therefore, characterized by an $^8S_{7/2}$ state having spin only, the theoretical ordered moment should be $_gJ = _gS = 7\ \mu_B$. The smaller value of the measured ordered moment as compared to the maximum theoretical value is also characteristic of other rare earth metals. Data on the product of magnetic moment times magnetic form factor (μf) can be obtained from the magnetic satellite diffraction peaks occurring at various scattering angles. These values from Eu are in reasonable agreement with similar values of μf obtained from the compound EuO. The magnetic intensity variation with temperature is proportional to $(T_N - T)^{1/2}$ over a considerable region below the Néel temperature. Data taken on the intensity of the nuclear peaks at four different sample temperatures above the Néel temperature over the range from 100° to 293°K indicate an apparent Debye temperature variation from about 70° to 122°K, respectively.

24,094 MAGNETIC STRUCTURE OF NEODYMIUM by R.M. Moon, J.W. Cable and W.C. Koehler (Oak Ridge Lab.); J. Appl. Phys., Vol. 35, pp. 1041-1042, Mar. 1964

Neutron diffraction measurements have been made on a single crystal of neodymium at temperatures between 1.6° and 20°K. The onset of magnetic ordering occurs at 19°K and the magnetic structure changes at 7.5°K. The crystal structure is hexagonal with a four-layer stacking sequence of type ABAC. Thus, alternate layers have different nearest-neighbor environments, either hexagonal or face-centered cubic. The main features of the diffraction pattern can be interpreted on the basis of an approximate model in which the hexagonal sites order at 19°K with an antiferromagnetic arrangement between alternate hexagonal layers and with a sinusoidal modulation within each layer. The propagation vector for this modulation and the direction of the magnetic moments are both in the basal plane along a b_1 reciprocal lattice vector. The magnitude of the propagation vector changes from $0.13\ b_1$ at 18°K to $0.11\ b_1$ at 7.5°K. The cubic sites order at 7.5°K with a similar structure, except that the propagation vector is $0.15\ b_1$ and the moments are in the basal plane at an angle of 30° from b_1. The amplitude of the modulated moments is 2.3 ± 0.2 Bohr magnetons for the hexagonal sites and 1.8 ± 0.2 Bohr magnetons for the cubic sites. This model fails to account for all the observed intensities but may be improved by adding a small modulated moment on the cubic sites in the upper temperature region which is shifted in phase by $1/2\pi$ from the modulation in the hexagonal layers, and by allowing the hexagonal moments to deviate slightly from the basal direction.

24,095 A NEUTRON DIFFRACTION INVESTIGATION OF THE MAGNETIC STRUCTURE OF $TbMn_2$ by L.M. Corliss and J.M. Hastings (Brookhaven Lab.); J. Appl. Phys., Vol. 35, pp. 1051-1053, Mar. 1964

$TbMn_2$ crystallizes with the cubic Laves-phase structure (C15-type) which may be regarded as the spinel structure without the anions. The "A" sites are occupied by Tb ions and the "B" sites by Mn ions. Neutron diffraction powder patterns run at 4.2°K exhibit a number of extra reflections characteristic of a modulated magnetic structure. These additional reflections can be indexed on the basis of a spiral modulation propagated along [110] with a wavelength of 8.0A. The spiral axis is along [001]. The "B" sites are ordered in a manner which is entirely analogous to the low-temperature ordering of Fe_3O_4; the two sublattice spirals being 180° out of phase. The A sublattice is in phase with a particular one of the two B sublattices. The combination of the internally compensated B sites and the ferromagnetically coupled A sites leads to a ferrimagnetic spiral.

24,096 MAGNETIC STRUCTURE INVESTIGATIONS AT THE NUCLEAR CENTER by E.F. Bertaut, G. Roult, A. Delapalme, G. Bassi, M. Mercier, A. Murasik, V. Van Qui (Ctr. d'Etudes Nuc., Grenoble, France), A. Aleonard, R. Pauthenet (Lab. d'Electrostat. Phys. Metal, Grenoble), M. Chevreton (Lab. Genie Chimi., Lyon) and R. Jansen (Comp. GE, Marcoussis); J. Appl. Phys., Vol. 35, pp. 952-953, Mar. 1964

The following structures are briefly described: $MnYO_3$. In this hexagonal layer structure there are fivefold coordinated Mn atoms. Their spins order below 46°K forming angles of 120° in the layer. Two different models may be inferred from powder data. The ambiguity is lifted by the fact that a weak ferromagnetism is observed. The ferromagnetic and the "120° model" must belong to the same representation which is here the identity representation. β-$FeNaO_2$. Each iron spin has 4 antiparallel neighbors. The antiferromagnetic axis is 0z. From group theory it is concluded that the weak ferromagnetism must be along 0y. $GeNi_2O_4$. Ni is on octahedral sites (B sites). Spin-ordering sets in below 15°K with doubling of the unit cell. The propagation vector of the antiferromagnetic arrangement is $k_0 = [\frac{1}{2}\frac{1}{2}\frac{1}{2}]$. The spin-value is S = 1.1. The true symmetry is rhombohedral. Cr_3X_4. Cr_3S_4 has a huge magnetic unit cell. The structure is antiferromagnetic. In Cr_3Se_4 the same large magnetic cell is observed, but at low temperatures a second antiferromagnetic mode is superimposed. In Cr_3Te_4 a ferromagnetic structure is observed at room temperature, but below 80°K an antiferromagnetic configuration is superimposed which explains that the magnetization at saturation is inferior to the sum of the moments of the individual atoms.

24,097 MAGNETIC PROPERTIES OF AN IRON-NICKEL SINGLE CRYSTAL ORDERED BY NEUTRON BOMBARDMENT by L. Néel, J. Pauleve, R. Pauthenet, J. Laugier and D. Dautreppe (Ctr. Nuc. et Lab. Electrostat. et Phys. Metal, Grenoble, France); J. Appl. Phys., Vol. 35, pp. 873-876, Mar. 1964

A new ordered structure can be obtained in an Fe-Ni (50%-50%) alloy, by irradiating it with neutrons below 320°C. This ordered structure is tetragonal (AuCu type) and leads to a very high magnetic anisotropy. The magnetic properties of a single-crystal disk irradiated with neutrons at 295°C, with an applied magnetic field along the [100] direction have been studied. The X-ray superlattice lines show that after irradiation the sample is made of small ordered crystallites with their tetragonal axes distributed along a [100], [010] direction. The study of the anisotropy energy in the sample plane [011], and the magnetization curves drawn for different directions, show that this sample presents the characteristics of a uniaxial substance. Expressing the anisotropy energy by $K_1 \sin^2\theta + K_2 \sin^4\theta$, it has been found that $K_1 = 3.2 \times 10^6$ ergs/cm³ and $K_2 = 2.3 \times 10^6$ ergs/cm³. This high value of K_2 is not in agreement with the conception of independent crystallites.

24,098 MAGNETIC STRUCTURES IN $FeCr_2S_4$ and $FeCr_2O_4$ by G. Shirane, D.E. Cox (Brookhaven Lab.), and S.J. Pickart (U.S. Naval Ord. Lab.); J. Appl. Phys., Vol. 35, pp. 954-955, Mar. 1964

The magnetic structures in $FeCr_2S_4$ and $FeCr_2O_4$ have been investigated by the powder neutron diffraction technique. From room temperature diffraction patterns, it is established that both compounds are normal spinels with sulfur and

ygen parameters u = 0.384 and 0.386, respectively. The $FeCr_2S_4$ specimen hibits a Néel temperature of 180°K, with $\sigma_0 = 1.6\ \mu_B$. The magnetic intensies of this compound at 4°K are in good agreement with those based on a sime Néel model with $\mu_{Fe} = 4.2\ \mu_B$ and $\mu_{Cr} = 2.9\ \mu_B$. The magnetic properties $FeCr_2O_4$ are, on the other hand, more complex. The moment σ_0 is considerly lower than the value expected from the Néel model. Moreover, the crysl becomes tetragonal with c/a < 1 around 135°K. The magnetic reflections 4°K show satellite peaks characteristic of a cone spiral structure described the theory of Menyuk, Dwight, Lyons, and Kaplan for tetragonal spinels. owever, a quantitative comparison of observed and calculated intensities incates that some modifications of the simple cone model are necessary. The tellite reflections disappear at 35°K, and the spin arrangement is collinear tween this temperature and the Néel temperature at 80°K.

4,099 NEUTRON DIFFRACTION INVESTIGATION OF A GADOLINIUM NGLE CRYSTAL by G. Will (USAERDL), R. Nathans (Brookhaven Lab.), and .A. Alperin (U.S. Naval Ord. Lab.); J. Appl. Phys., Vol. 35, pp. 1045-046, Mar. 1964

single-crystal disk of Gd cut parallel to (00.1) has been studied in zero magtic field. A careful search along and perpendicular to the c* axis in the ighborhood of the (00.2) reflection has failed to reveal any satellites in the mperature range 77° to 290°K. Thus unlike the rare-earth elements from Tb Tm, gadolinium is a normal ferromagnet. Above 248°K, the moment is aligned along the c axis. Below this temperature, the moments make an angle with e c axis which reaches a maximum of 75° at 195°K and approaches 30° at °K. The coherent nuclear scattering amplitude has been estimated by scaling e nuclear scattering to the magnetic scattering in the (00.2) reflection. The sult is $|b| = 1.5 \pm 0.2 \times 10^{-12}$ cm.

4,100 SPIRAL STRUCTURE AND MOMENTS IN Gd-Dy ALLOYS by R.M. bzorth and J.C. Suits (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 039-1040, Mar. 1964

agnetic moment and electrical resistivity measurements of the Curie (T_c) and Néel (T_N) points of Gd-Dy alloys show that the region of spiral structure bewen T_c and T_N narrows as Gd is added to Dy and disappears at about 50 at. er cent Gd. Apparently no spiral structure exists in Gd or Gd-rich alloys. The agnetic moments of Dy-rich alloys show the saturation expected when the agnetization is confined to the hexagonal plane ($Jg\pi/4$), but the moments radually approach the theoretical Jg as the Gd content increases toward 100 er cent. The spin disorder resistivities are not linear in $(g-1)^2J(J+1)$; this uggests a variation in the electronic structure of these alloys.

Magnetic Structure of YIG (Ion Substituted) - See 24,167

4,101 MAGNETIC TRANSITIONS IN DYSPROSIUM ALUMINUM GARNET y M. Ball, W.P. Wolf and A.F.G. Wyatt (Clarendon Lab.); J. Appl. Phys., ol. 35, pp. 937-938, Mar. 1964

Measurements of the susceptibility, internal energy, entropy, and magnetizaion of dysprosium aluminum garnet in the region of the Néel temperature are ompared with recent theoretical calculations for Ising models. In general, ood agreement is found but there are some quantitative discrepancies which re probably due to the neglect of long range dipolar forces in the theories.

4,102 MAGNETIC TRANSITION LAYER SPIN CONFIGURATION by R.F. oohoo (California Inst. Tech.); J. Appl. Phys., Vol. 35, pp. 927-928, Mar. 964

The spin configuration in the transition layer between an antiferromagnet and ferromagnet is investigated. The calculation is carried out by minimizing the ree energy of the system with exchange, anisotropy, magnetostatic, and Zeeman terms. The results of the calculation indicate that a domain wall is formed etween the antiferromagnetic and ferromagnetic media. The configuration of he walls, although similar to that in ferromagnets, is more complex and sensitively dependent upon the relative values of the exchange constant and anisotropy for the two media as well as upon the strength and nature of the interaction across the interface. A specific example involving an oxidized ferromagnetic film is given to illustrate the utility of the general result. It is noted that the formation of an antiferromagnetic-ferromagnetic domain wall may influence the magnetization of and surface spin pinning in thin films.

Magnetic Transitions in Gd - See 23,966

24,103 PROTON MAGNETIC RESONANCE IN PARAMAGNETIC AND ANTIFERROMAGNETIC $CoCl_2 \cdot 6H_2O$ by E. Sawatzky and M. Bloom (U. British Columbia, Vancouver); Canadian J. Phys., Vol. 42, pp. 657-677, Apr. 1964

The transition temperature T_N of $CoCl_2 \cdot 6H_2O$ has been measured as a function of applied field and crystal orientation using the proton resonance lines, since they are very sensitive functions of temperature near T_N. T_N was found to be a complicated function of the applied field and crystal orientation, which cannot be described by the molecular field approximation. The transition is gradual rather than sudden and coexistence of the NMR spectra associated with the paramagnetic and antiferromagnetic phases was observed over a temperature region of about 10^{-2}°K. Short-range order effects were observed near T_N in the form of anomalous broadening of the magnetic resonance lines. The magnetic susceptibility in zero field was measured along the preferred axis of antiferromagnetic alignment. This, together with specific heat data from published literature, was used to show a mutual consistency between thermodynamic variables and the dependence of T_N on H in low fields as obtained by NMR. The treatment follows that of Buckingham and Fairbank for the λ transition in liquid helium. The sublattice magnetization in the antiferromagnetic phase was measured as a function of temperature. It was found to depend logarithmically on $(T_N - T)$, for all values of applied field.

24,104 MAGNETIC PROPERTIES OF SmIG by E.R. Bauminger, L. Grodzins (MIT) and M. Schieber (Harvard U.); Bull. Am. Phys. Soc., Vol. 9, p. 226(A), Mar. 1964

Bulk magnetization measurements on SmIG show a small, almost temperature-independent magnetic moment associated with the Sm sublattice. The Mössbauer effect was used as a small microscopic probe to determine the hyperfine field at Sm nuclei as a function of temperature. A large and strongly temperature-dependent hyperfine field was found in the range $20°K \leq T \leq 300°K$ [e.g., $\sim 2 \times 10^6$ oe at 20°K, and $\sim 0.5 \times 10^6$ oe at 300°K].

24,105 VARIATION OF THE INTERNAL FIELDS AND ISOMER SHIFTS AT THE Fe SITES IN THE FeAl SERIES by M.B. Stearns (Ford Motor); J. Appl. Phys., Vol. 35, pp. 1095-1096, Mar. 1964

The Mössbauer technique has been used to measure the internal magnetic fields and isomer shifts of Fe^{57} atoms residing at the various sties in the FeAl series. Alloys of Al content varying from 0 to 50 at.% were studied. In the disordered region (< 21 at.% Al) five different type sites were observed, corresponding to Fe atoms having 8 through 4 nearest-neighbor (nn) Fe atoms. The internal field decreased by about 0.07 H_{Fe} for each nn Al atom. In the ordered region sites having 8 through 2 nn Fe atoms were observed. For A type sites (4 nn Fe atoms and 4 nn Al atoms at 25 at.% Al) the internal field decreased by 0.11-0.12 H_{Fe} for each nn Al atom. In the region above about 30 at.% Al the alloys are not ferromagnetic but information on the type ordering could be obtained from the isomer shifts. Over the whole series the isomer shift indicated that there is progressively less electronic charge at the nucleus as the number of nn Al atoms increased.

24,106 MAGNETIC MOMENTS AND UNPAIRED SPIN DENSITIES IN THE Fe-Rh ALLOYS by G. Shirane, R. Nathans (Brookhaven Lab.) and C.W. Chen (Westinghouse); Bull. Am. Phys. Soc., Vol. 9, p. 212(A), Mar. 1964

The distribution of magnetic moments in the Fe-Rh system has been investigated by the neutron-diffraction technique in the composition range between 35 and 50 at.% Rh. The alloys have chemical order of CsCl type; the body corner positions are occupied by FeI atoms and the body centers by Rh and FeII. The magnetic moments in ferromagnetic alloys containing 35 %, 40%, and 48 % Rh are $\mu_{FeI} = 3.1\ \mu_B$, $\mu_{FeII} = 2.5\ \mu_B$, and $\mu_{Rh} = 1.0\ \mu_B$ at 25°C. The moment of the FeI atom in the 50 % Rh alloy, which is antiferromagnetic at room temperature, increases to $3.3\ \mu_B$. A detailed study of the unpaired spin-density distribution in the 48 %-Rh alloy was made by the polarized beam technique. While the FeI atom has a nearly spherical density distribution, that of the Rh atom shows a strong tendency towards e_g symmetry. The coherent nuclear-scattering amplitude of Rh was determined to $0.585 \pm 0.005 \times 10^{-12}$ cm.

MAGNETOSTRICTION, MAGNETOELASTICITY, AND PIEZOMAGNETISM

24,107 MAGNETOSTRICTION OF SINGLE-CRYSTAL DYSPROSIUM, GADOLINIUM IRON GARNET, AND DYSPROSIUM IRON GARNET by A.E. Clark, B.F. DeSavage and E.R. Callen (U.S. Naval Ord. Lab.); J. Appl. Phys., Vol. 35, pp. 1028-1029, Mar. 1964

The temperature and field dependences of the magnetostriction of dysprosium single crystals were measured from 78°K to room temperatures. In the paramagnetic region (T > 178°K), the six lowest-order coefficients were measured and were found to vary as H^2. At lower temperatures, due to the large uniaxial anisotropy, only the basal plane coefficient was measurable. The temperature and field dependences of this coefficient are adequately represented by the single-ion magnetoelastic coupling theory and are given as a function of the moment by $\lambda \approx 8.7 \times 10^{-3}\ I_{5/2}[\mathcal{L}^{-1}(m)]$. The temperature dependences of the magnetostriction coefficients of single-crystal GdIG and DyIG were measured from 78° to 400°K and found to be much larger and of opposite sign than that of YIG over most of the temperature range. This is due to the larger magnetoelastic coupling coefficient of the rare-earth ions. Among the several interesting features are: the observance of magnetostriction compensation points, the sharp dip (and change of sign) of the apparent saturation magnetostriction at the magnetization compensation points, and the reversal in sign of the forced magnetostriction.

Magnetostriction in Ferromagnets - See 24,165

24,108 MAGNETOELASTIC WAVES IN YTTRIUM IRON GARNET by W. Strauss (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 1022-1023, Mar. 1964

Magnetoelastic RF pulses with magnetically controlled echo time have been observed in a rod of yttrium iron garnet. Data were taken at room temperature in the frequency interval 0.5 to 3.3 Gc/sec with power input in the milliwatt range. Excitation and detection were accomplished by placing a wire antenna near an optically flat end-face of the rod. A nonuniform internal magnetic field was obtained by applying a steady, uniform external field parallel to the rod axis. The frequency-time-magnetic field characteristics have been measured. The behavior of these pulses can be explained in terms of a magnetoelastic disturbance traveling along the rod axis. It originates at that position along the axis where $\omega_c = \gamma H_i$. From there the disturbance travels to the nearer polished surface where it is reflected. On arrival back at the launch site a fraction of the energy is detected and the remainder reflected for another round trip. The process is repeated several times to give rise to a pulse sequence.

24,109 INTERNAL MAGNETOELASTIC COUPLING CONSTANT OF NICKEL FERRITE by N. Goldberg and W. McCann (UNIVAC); J. Appl. Phys., Vol. 35, pp. 1026-1027, Mar. 1964

The coupling of the spin system to ionic displacements in a ferromagnetic crystal can cause displacements of the ions which do not result in external strains. A search has been made for such magnetostrictive displacements of the oxygen ions in nickel ferrite by looking for a change in the intensity of the 442 X-ray diffraction line. The sample was a disk-shaped single crystal of nickel ferrite cut so that the face of the sample was a (221) plane. The intensity of the line when the magnetization was perpendicular to the disk was compared with the intensity when the magnetization was essentially in the plane of the disk near a [111] (easy) direction; these intensities were found to be equal to within 0.5 per cent. The equilibrium ionic displacements were expressed in terms of the internal magnetoelastic coupling constants, assuming plausible modes of displacement of the oxygen ions. Changes in the structure factor of the 442 line resulting from these displacements were calculated. From these results and the upper limit for the fractional difference in the X-ray intensity, it is found that $B_{int}\ ^{\gamma} \leq 1.6 \times 10^8$ and $B_{int}\ ^{\epsilon} \leq 0.8 \times 10^8$, where $B_{int}\ ^{\gamma}$ and $B_{int}\ ^{\epsilon}$ are phenomenological magnetoelastic coupling constants appropriate to oxygen displacements belonging to the Γ_γ representation and Γ_ϵ representation, respectively. Similar measurements on cobalt ferrite have been initiated, and changes in the intensity of the X-ray diffraction line have been observed as the magnetization direction was changed. Preliminary results yield values of B_{int} at least ten times as large as in nickel ferrite.

24,110 PIEZOMAGNETISM OF BIASED FERRITES by A.P. Greifer (Clevite); J. Appl. Phys., Vol. 35, pp. 1065-1066, Mar. 1964

New developments in the synthesis and processing of magnetostrictive materials that are highly piezomagnetic in the polarized state are briefly described and interpreted in terms of the relationship for reversible stress sensitivity derived by Bozorth and Williams. In the system MnO-CoO-Fe_2O_3, a coupling coefficient 0.39 has been obtained for $Mn_{0.970}Co_{0.068}Fe_{1.962}O_4$ and 0.33 for $Mn_{0.932}Co_{0.068}Fe_2O_4$. Solid solutions of the nickel cobalt and manganese cobalt ferrites are also piezomagnetic. These materials require atmosphere control during the firing process. When similar processing is applied to the commercially established nickel cobalt ferrites, a coupling coefficient 0.42 is obtained for $Ni_{0.974}Co_{0.026}Fe_2O_4$ without requiring quenching from high temperatures. It is suggested that the high piezomagnetic activity of the manganese cobalt ferrites can be understood if the appropriate strain term in the expression derived by Bozorth and Williams is better identified by the easy direction magnetostriction instead of the polycrystalline magnetostriction. This interpretation leads to the prediction that magnetite with the correct cobalt ferrite addition is highly piezomagnetic.

FERRO- AND FERRIMAGNETISM

GENERAL

Ferromagnetic Exchange - See 24,091

24,111 THE EFFECTS OF RADIATION ON FERRITES by S. Taimuty and J. Mills (Stanford Res. Inst.); Commun. and Electronics, No.66, pp. 305-308, May 1963

The effects of reactor exposures in the range of 10^{16}-10^{18} fast neutrons per square centimeter (cm^2) on the magnetic properties of 16 polycrystalline ferrites and garnets are presented. Measured properties included coercive force, remanence, saturation induction, complex permeability, and FMR (ferromagnetic resonance) linewidth. It was found that the hysteresis properties and FMR linewidth were slightly affected by exposures of 10^{18} neutrons per cm^2. Complex permeability was effected by exposures as small as 10^{16} neutrons per cm^2. The magnitudes of the observed changes were small and it is likely that the operation of devices incorporating these materials will not be significantly affected by such changes.

24,112 IRRADIATION OF IRON AND 5-79 Mo PERMALLOY WITH 2-Mev ELECTRONS by D.I. Gordon and R.S. Sery (U.S. Naval Ord. Lab.); J. Appl. Phys., Vol. 35, pp. 879-880, Mar. 1964

Large changes in the structure-sensitive magnetic properties of bulk polycrystalline 5-79 Mo Permalloy resulted from irradiation with 2-Mev electrons at $\sim 10^{17}$ electrons/cm^2 at temperatures ranging from 60° to 170°C. These changes showed an approximately linear dependence on sample thickness from 0.10 to 0.25 mm. In addition, extreme rectangularities in the magnetization curves and hysteresis loops were obtained. For example, the maximum slope of the magnetization curve for a 0.10-mm sample increased from $\Delta B/\Delta H = 0.3 \times 10^6$ to $\Delta B/\Delta H = 4.3 \times 10^6$. This unusual steepness is evidence of the effectiveness of electron irradiation in influencing order in 5-79 Mo Permalloy at temperatures well below the ordering temperature, and without an applied magnetic field. Iron, irradiated under the same conditions, showed no changes in its magnetic properties.

24,113 INVESTIGATIONS OF THE EFFECTS OF NEUTRON AND He^3 IRRADIATION ON THE MAGNETIC PROPERTIES OF PERMALLOY THIN FILMS by A.I. Schindler and C.M. Williams (U.S. Naval Res. Lab.); J. Appl. Phys., Vol. 35, pp. 877-879, Mar. 1964

Measurements have been made on the changes in the magnetic anisotropy energy and hysteresis loop parameters of evaporated Permalloy thin films resulting from 2.2 Mev He^3 irradiation and from reactor neutron irradiation. Only minor changes were observed following an irradiation of 1.6×10^{14} He^3 particles/cm^2. However, a total irradiation of either approximately 10^{17} neutrons/cm^2, or 8 to 9×10^{16} He^3 particles/cm^2, yielded the following general results: Regardless of the magnetic state of the sample, the uniaxial anisotropy energy K_u increased (up to 200 per cent) when irradiations took place in zero applied field. Similar increases were noted as a result of either neutron irradiation with a saturating magnetic field along the easy axis or He^3 irradiation with a saturating magnetic field either parallel or perpendicular to the easy axis. A decrease of ~50 per cent in K_u resulted from neutron irradiation when the saturating magnetic field was applied perpendicular to the easy axis. Rotation of the easy axis, up to 78°, occurred for either neutron or He^3 irradiation with a saturating magnetic field applied perpendicular to the easy axis. The more significant hysteresis loop modifications observed were the development of constricted loops (measured in the hard direction) for most of the samples irradiated in zero applied field, and decreases in the coercive force up to 28 per cent (measured in the easy direction) of most of the irradiated samples.

24,114 AGING AND STABILIZATION OF ELECTRODEPOSITED CYLINDRICAL MAGNETIC THIN FILMS by J.T. Chang, U.F. Gianola and M.W. Sagal (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 830-831, Mar. 1964

The effects of aging cylindrical magnetic film elements are described. The films are 1μ thick, circumferentially anisotropic, and electrodeposited upon a 125-μ (0.005-in.) diameter wire substrate. The values of skew and dispersion undergo considerable changes even when the films are stored at room temperature. The results of aging at 55°C under a variety of applied magnetic fields are described. Measurements are given for skew, dispersion, anisotropy, and coercive fields. Under worst case conditions, all parameters experience changes several times their initial values. The changes tend toward terminal values, and the degradation of the important magnetic parameters is clearly influenced by the transverse fields during the aging process. Experimental data showing a possible stabilization of the film by field annealing in an easy direction field following electrodeposition are discussed.

24,115 MAGNETIC PROPERTIES OF Ni-Fe-Cr FILMS by M.S. Cohen (Lincoln Lab.); J. Appl. Phys., Vol. 35, pp. 834-835, Mar. 1964

Films of Ni-Fe-Cr were vapor deposited on heated glass substrates in vacuum. In each preparation increasing amounts of Cr were added to the original Ni-Fe source, and a fresh set of glass substrates was exposed to the vapor beam after each Cr addition. In this way, Cr contents ranging from 0% to about 5% were produced in different films in each preparation, while Ni-Fe ratios of various preparations ranged from 78% Ni, 22% Fe to 90% Ni, 10% Fe. For all Ni-Fe ratios the anisotropy field H_k, the magnetization M, and the wall coercive force H_w, decreased monotonically with Cr content, while angular dispersion and electrical resistivity ρ increased with Cr content. The variations of M and ρ with Cr content were consistent with bulk data. The empirical relation $H_k = A(M-B)$ was found valid except for very small or very large additions of Cr; the constants A and B were independent of the initial Ni-Fe ratio but dependent on the substrate temperature. Addition of Cr always tended to make the magnetostriction more positive, regardless of the initial Ni-Fe ratio.

24,116 STRESS EFFECTS IN EVAPORATED PERMALLOY FILMS by H.L. Pinch and A.A. Pinto (RCA); J. Appl. Phys., Vol. 35, pp. 828-831, Mar. 1964

The magnetic properties of evaporated Permalloy films subject to external uni-

rm stresses were experimentally determined and the resulting changes in magtude and direction of H_K were compared to recently reported theories. In neral, qualitative agreement between the data and theory was found when e angular dispersion resulting from the stress was small. When the stress inced dispersion was large, the discrepancies between data and theory became uite large. Some of the discrepancy in H_K may be due to instrumental difficulties in measuring H_K under conditions of large angular dispersion. The variion of H_C with stress follows that of H_K, but in a much less sensitive manner. hen H_K exhibited a minimum, H_C showed a corresponding minimum while the spersion and the hard axis coercivity had corresponding maxima. The stressduced interchange of the easy and hard axes was found to proceed partially rough a rotation of axes and not by just the anisotropy decrease predicted by eory. The axis rotation under these conditions is due to the excessive angular spersion, the nonuniform nature of films, and the slight differences between e effects of tension and compression.

4,117 PROPERTIES OF MOLYBDENUM-PERMALLOY FILMS by K.Y. Ahn nd W.R. Beam (Rensselaer Polytech. Inst.); J. Appl. Phys., Vol. 35, pp. 832-35, Mar. 1964

ernary alloy films have been produced by variable-ratio sequential and simulaneous two-source evaporation under conditions comparable to those of techtical Permalloy film evaporation. Intrinsic film properties measured at Mo conentrations up to 6%-8% indicated reductions of M, M_c, H_k, and dispersion. t high Mo concentrations, oblique incidence produced strong anisotropies. rystallite dimensions were substantially less than in normal Permalloy films, nd increased resistance to annealing was observed.

Magnetization of Films - See 24,213

4,118 MAGNETIC PROPERTIES OF CUBE-TEXTURED 6-81.3 Mo-PERMALOY by Y. Odani (NTT); J. Appl. Phys., Vol. 35, pp. 865-866, Mar. 1964

study has been made of the magnetic properties of Mo-Permalloy sheets conaining 5.3%-6.8% Mo and 79.5%-82.5% Ni that were cold rolled and anealed to obtain a nearly perfect (100)[001] texture. Square hysteresis loops ere obtained only in compositions of about 81.3% Ni quenched from temperatures greater than 500°C, in hydrogen. Magnetic properties of spiral cores ade of insulated 0.05 mm thick 6-81.3 Mo-Permalloy tapes were as follows: a) When annealed at 1150°C to prevent secondary recrystallization, a square oop with $\mu_m = 1200{,}000$, $\mu_0 \leq 10{,}000$, $H_c = 0.004$ oe, and $M_r/M_s = 0.92$ as obtained. (b) When annealed at 1170°C, secondary recrystallization occurred; the μ_0 of the core was increased to 160,000.

4,119 SPINEL-TYPE FERRITES CONTAINING FLUORINE by M. Schieber Harvard U.); J. Appl. Phys., Vol. 35, pp. 1072-1073, Mar. 1964

Charge compensation by substituting univalent fluorine for divalent oxygen in pinel type ferrites has been studied by preparing and analyzing single-phase olycrystalline materials. Starting with a 1:1 molar ratio of divalent fluorides nd Fe_2O_3, charge compensation was mainly achieved by metal vacancies, although some Fe^{2+} was also present. The preparative method, unit cell dimensions, chemical compositions, magnetic moments at 90°K and Curie points for hese compounds are given. Their properties can be interpreted as those of solid solutions of mainly γ-Fe_2O_3 and a stoichiometric fluorine ferrite $M_2^{2+}Fe^{3+}O_3^{2-}F^-$, where M is Mg, Mn, Co, Ni, or Zn.

24,120 NEW DUCTILE MAGNETIC ALLOY HAS HIGHEST KNOWN REMANENCE; Bell Lab. Record, Vol. 42, p. 102, Mar. 1964

A cobalt-iron-vanadium alloy called Remendur has been developed which is capable of values of remanence up to 21,500 gauss. Remendur has a high Curie point, a square hysteresis loop for efficient switching, a temperature stable coercive force, and essentially isotropic magnetic properties. Mechanically, Remendur has a high elastic modulus, an expansion coefficient to match glass; it can be readily electroplated, responds to simple heat treatment, yet is ductile enough to be processed into foil, wire, or ribbon.

24,121 FERRIMAGNETIC GARNETS CONTAINING PENTAVALENT VANADIUM by S. Geller, G.P. Espinosa, H.J. Williams, R.C. Sherwood and E.A. Nesbitt (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 570-572, Mar. 1964

Magnetic and crystallographic data are reported on the system $\{Y_{3-2}Ca_{2x}\}[Fe_2](Fe_{3-x}V_x)O_{12}$. It appears that for all values of x, $0 < x \leq 1.5$, Curie temperatures are higher than would have been expected. To $x \cong 0.7$, the Curie temperatures are equal to or slightly greater than that of yttrium iron garnet (YIG) itself, then decrease gradually to 493°K for $\{Ca_3\}[Fe_2](Fe_{1.5}V_{1.5})O_{12}$. Garnets in the system $\{Bi_{3-2x}Ca_{2x}\}[Fe_2](Fe_{3-x}V_xO_{12}$ with $1.5 > x > 0.8$ exist. The magnetic behavior of the garnet $\{Bi_{0.5}Ca_{2.5}\}[Fe_2](Fe_{1.75}V_{1.25})O_{12}$ is essentially the same as that of the yttrium analog. Pentavalent vanadium substitution thus provides lower moment garnets with high Curie temperatures and including Bi^{3+} ion substitution, ferrimagnetic garnets not containing rare earths or yttrium.

24,122 FERRIMAGNETIC GARNETS CONTAINING PENTAVALENT ANTIMONY by S. Geller, H.J. Williams, G.P. Espinosa, and R.C. Sherwood (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 542-547, Mar. 1964

Pentavalent antimony may be substituted for Fe^{3+} ions in iron garnets when appropriate electrostatic compensation is made. It appears that the Sb^{5+} ion prefers octahedral sites exclusively. Magnetic and crystallographic data are reported on the systems $\{Y_{3-2x}Ca_{2x}\}[Sb_xFe_{2-x}](Fe_3)O_{12}$ and $\{Ca_3\}[Sb_xFe_{2-x}]-(Fe_{1.5+x}V_{1.5-x})O_{12}$, the latter is the system obtained from solid solutions between the end member $\{Ca_3\}[Sb_{1.5}Fe_{0.5}](Fe_3)O_{12}$ of the former and the previously reported ferrimagnetic garnet $\{Ca_3\}[Fe_2](Fe_{1.5}V_{1.5})O_{12}$. Magnetic and crystallographic data are also given on four other garnets involving substitution of Sb^{5+} ions. Results are compared with those from systems in which di, tri, and tetravalent nonmagnetic ions are substituted for Fe^{3+} ions in YIG (yttrium iron garnet). An important conclusion is the corroboration of the idea that the particular nonmagnetic ion substituent affects the magnetic behavior, probably as a result of the nature of the chemical bonding of the particular ion. Probably most interesting is the result that the Sb^{5+} ion provides additional ferrimagnetic garnets not containing rare earths or yttrium.

24,123 LOW-TEMPERATURE PROPERTIES OF DILUTE FERROMAGNETS IN COPPER by M.W. Klein (Sperry Rand Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 944-945, Mar. 1964

The low-temperature properties of dilute magnetic impurities in copper are studied, using an extension of the recently developed statistical theory of Klein and Brout. A Ruderman-Kittel (RK) interaction is assumed to exist between the magnetic impurites. The probability distribution of the effective field about an impurity, due to all other impurities of the system, is obtained. The variation of the probability distribution as a function of the impurity concentration, temperature, and JS^2, where J is the strength of the Ruderman-Kittel interaction and S is the magnitude of the impurity spin, is briefly discussed. Using this distribution function, the model explains the low-temperature specific heat of dilute copper-cobalt and copper-iron. Copper-manganese has been explained previously by the same model. The fact that the Ruderman-Kittel potential explains the low-temperature specific heat of all three substances gives additional support to the theory that this potential, rather than Overhauser's spin-density waves, is the correct interaction mechanism between dilute magnetic impurities in a nonmagnetic conductor. The detailed shape of the probability distribution and its variation with temperature is in qualitative agreement with recently obtained Mössbauer data on dilute Cu-Fe.

24,124 FERROMAGNETISM AND INCIPIENT SUPERCONDUCTIVITY IN A $CeRu_2$+7.3% $GdRu_2$ ALLOY by J.J. Drautman, C.J. Anderson and R. Del Grosso (Malaker Lab.); J. Appl. Phys., Vol. 35, pp. 974-975, Mar. 1964

The susceptibility, magnetic moment, and resistivity of an alloy of $CeRu_2$+7.3 per cent $GdRu_2$ prepared by arc melting have been measured in the range 1.3° to 20°K. This alloy has been previously reported to be both ferromagnetic and superconducting. The sample is weakly ferromagnetic, and undergoes a superconducting transition which reduces the positive susceptibility. The resistance becomes smaller at the transition temperature, but does not become zero. The transition temperature in zero field is in good agreement with that previously reported.

24,125 FERROMAGNETIC EUROPIUM COMPOUNDS by T.R. McGuire and M.W. Shafer (IBM Watson Res.Ctr.); J. Appl. Phys., Vol. 35, pp. 984-988, Mar. 1964

Information on ferromagnetism in several divalent europium compounds (europium chalcogenides, europium halogens, and europium silicates) is summarized and theoretical results are reviewed. The europium chalcogenide series all have the rocksalt structure, the oxide, sulfide, and selenide being ferromagnetic. Detailed moment, specific heat, and nuclear magnetic resonance measurements are available for EuS. Theoretical analysis indicates that there is positive exchange between nearest-neighbor europium atoms which decreases with increasing atom spacings. There is also a weaker negative superexchange via the anions in these compounds which is responsible for antiferromagnetism in EuTe. The EuTe magnetic ordering has been studied by neutron diffraction and the sublattice magnetization-temperature behavior is found to be somewhat anomalous. EuSe is ferromagnetic but reveals low-field magnetization curves that have an unusual shape. EuS seems to be the simplest of the group so that fundamental parameters obtained from analyzing the data are probably the most reliable. In the halogen group, EuI_2 appears to be ferromagnetic while EuF_2 is apparently antiferromagnetic. The latter behavior is somewhat unexpected from interatomic distance considerations which hold for the chalcogenides. Of three silicates prepared, two were ferromagnetic. The most interesting was Eu_2SiO_4 which was obtained as transparent single crystals. Magneto-optical studies show this compound to have a Verdet constant higher than any other previously reported.

24,126 NEW FERROMAGNETIC 5:2 COMPOUNDS IN THE RARE-EARTH-PALLADIUM SYSTEMS by A.E. Berkowitz, F. Holtzberg and S. Methfessel (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 1030-1031, Mar. 1964

Gd_5Pd_2 is ferromagnetic below 335°K. The isostructural $Tb_{5.10}Pd_{1.90}$, $Dy_{5.07}Pd_{1.93}$, and $Ho_{5.04}Pd_{1.96}$ have paramagnetic metamagnetic transitions at 62°, 41°, and 27°K, respectively, and become ferromagnetic at lower temperatures with extremely high hysteresis. Energy products $(B \times H)_{max} = 20$ to 26×10^6 Goe at 4.2°K have been observed.

24,127 FERROMAGNETISM IN RARE-EARTH GROUP VA AND VIA COMPOUNDS WITH Th_3P_4 STRUCTURE by F. Holtzberg, T.R. McGuire, S. Methfessel and J.C. Suits (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 1033-1038, Mar. 1964

The structural, electric, and magnetic properties of the metallic 4:3 compounds and the 2:3 rare-earth semiconductors have been investigated with specific reference to gadolinium, for which the S ground state gives the minimum crystal field effect. Gd_4Bi_3 and Gd_4Sb_3 are both ferromagnetic with a saturation magnetization obeying the spin-wave $T^{3/2}$ law up to 0.8 of the Curie temperature. The Curie temperature T_C varies in the solid solution system Gd_4Sb_3-Gd_4Bi_3 with composition from 260° to 340°K. The semiconducting compound Gd_2Se_3 (ρ_{RT} = 3 Ω cm) has been found to be antiferromagnetic below $T_N = 6$°K. Solution of Gd in the holes of the defect Th_3P_4 structure decreases the electrical resistivity without a measurable variation of lattice constant ($a_0 = 8.718$ A). With increasing conductivity the material changes from antiferromagnetic to ferromagnetic. At the composition $Gd_{2.1}Se_{2.9}$ the Curie temperature is $T_C = 80$°K with $\rho_{RT} = 1.4 \times 10^{-3}$ Ω cm. The relation between Curie temperature and electrical resistivity has been examined by introducing the same spin concentration into Gd_2Se_3 by Eu^{2+} doping. The semiconductor $Eu_{0.5}Gd_{1.6}Se_{2.9}$ is paramagnetic. However, $Y_{0.5}Gd_{1.6}Se_{2.9}$ has low resistivity and is ferromagnetic below T_C = 47°K.

Ferromagnetic $MnYO_3$ - See 24,096

THEORY

24,128 BAND THEORY OF FERROMAGNETISM: QUALITATIVE ASPECTS by F. Englert and M.M. Antonoff (Libre de Bruxelles, Belgium); Physica, Vol. 30, pp. 429-444, Mar. 1964

A discussion of the band model of a ferromagnet through an analysis of spin excitations is presented. The occurrence of a phase transition is related to the appearance of a collective spin-wave mode in addition to individual Stoner-like excitations. Various kinds of phase transitions (ferromagnetism, antiferromagnetism, static spin density waves) may appear, depending on the wave-vector at which a zero frequency collective mode appears. The nature of the collective mode in the ferromagnetic case is related to electron-lattice binding and to temperature; in particular it is shown that all the results of the random phase approximation for a Heisenberg ferromagnet (and antiferromagnet) can be obtained from the band theory in a suitable limit. The importance of electron correlation effects on the magnetization curve is shown and a basis for a quantitative theory of ferromagnetism in solids is given.

24,129 BAND THEORY OF FERROMAGNETISM, ANTIFERROMAGNETISM, AND SPIN WAVES by D.C. Mattis (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 1085-1086, Mar. 1964

Intra-atomic exchange (Hund's rule mechanism) and Heisenberg nearest-neighbor exchange are examined for their role in the ferromagnetism of metals with degenerate bands. The equations of motion of spin waves valid near T = 0°K are derived, and a number of branches are found. When the equations are solved in the approximation that $k_F \ll$ size of the Brillouin zone, the spin waves all have positive energy, and have wave vectors not exceeding 0.9 k_F in magnitude. When the electrons approximately half-fill the Brillouin zone, it is possible for some spin waves to have negative energy, and for an antiferromagnetic state to become stable. This is not proved but indicated on the basis of an earlier calculation that also showed that ferromagnetism is less stable against antiferromagnetism in face-centered cubic materials than in either the simple, or body-centered cubic structures.

24,130 ON THE SIGN OF THE EXCHANGE INTEGRAL IN TRANSITION METALS by R.J. Weiss (Imperial Coll., London); Phil. Mag., Vol. 9, pp. 361-365, Mar. 1964

A qualitative picture of the electronic structure of ferromagnetic and antiferromagnetic metals and alloys is given. Ferromagnetism occurs when half the 3d states are completely filled (the other half only partially), while antiferromagnetism occurs when neither half of the 3d state is completely filled. Gamma iron appears to be an example of a metal that can exist in both forms.

24,131 FERROMAGNETISM — A MANY-BODY APPROACH by H. Brooks and A.K. Rajagopal (Harvard U.); Bull. Am. Phys. Soc., Vol. 9, p. 291(A), Mar. 1964

The ferromagnetism of a gas of electrons at T = 0°K interacting through a Yukawa potential is studied by using a matrix Green's function method. The Yukawa interaction is here chosen as it includes as special cases both the Coulomb and the short-range Stoner interactions, in addition to showing the effects of the range of interaction on ferromagnetism. The ground-state properties are studied in the Hartree-Fock approximation. It is shown that the gas behaves essentially like a Coulomb gas for the screening constant much smaller than the diameter of the ferromagnetic Fermi sphere. In this case, the transition from paramagnetic to the ferromagnetic state at T = 0°K is abrupt as a function of increasing coupling constant, the intermediate polarizations being relative maxima. For the screening constant much larger than the diameter of the ferromagnetic Fermi sphere, the interaction has short range and the transition from the paramagnetic to the ferromagnetic state is gradual. This model also exhibits low-lying excitations of the spin-wave type. The coefficient of the q^2 term is computed in the random-phase approximation. This result agrees with that derived by Herring for both the Coulomb and the Soner gases.

24,132 EXCHANGE INTERACTION THROUGH CHARGE CARRIERS IN ORDERED MAGNETIC SEMICONDUCTOR MATERIALS by B.V. Karpenko and A.A. Berdyshev (Gor'kii Ural State U.); Soviet Phys.-Solid State, Vol. 5, pp. 2215-2216(L), Apr. 1964

Indirect exchange interaction in semiconductors is discussed. It is concluded that there exist two types of interactions: antiferromagnetic and ferromagnetic interactions through charge carriers. The antiferromagnetic interaction is almost independent of temperature and predominates at low temperatures. As the temperature is increased, the ferromagnetic interaction becomes stronger and may exceed the antiferromagnetic interaction at a certain temperature T_C.

24,133 SPIN WAVES IN EuS by S.H. Charap (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, p. 988, Mar. 1964

The ferromagnetic compounds of Eu^{2+} have been studied as nearly ideal examples of the Heisenberg model. Measurements of the zero-field specific heat and magnetization of powdered EuS in the liquid-helium temperature region have recently been reported. The data were separately analyzed in terms of simple spin-wave theory to give rather indefinite results, especially for the second neighbor exchange. But together these data provide an unprecedented opportunity to test the Heisenberg model. By numerical calculation values of the exchange integrals between first neighbors (J_1) and second neighbors (J_2) as well as an average field H acting in the domains (presumably due to anisotropy and dipolar fields) were sought which would simultaneously produce good fits to both the specific heat and magnetization. It was found that $J_1/k_B = 0.20° \mp 0.01$°K, $J_2/k_B = -0.08° \mp 0.02$°K, and H = 4±2 koe. By combining the Rushbrooke and Wood value for the transition temperature T_C when $J_2 = 0$ with the molecular field result for the dependence of T_C on J_2 one may calculate from the above values $T_C = 15.8° \pm 0.6$°K. The paramagnetic Curie point is calculated to be 20.1°±0.8°K. These are in good agreement with measured values. The origin of the large field H is not known, but it is consistent with the field required to saturate powdered EuS.

24,134 SELF-CONSISTENT CORRELATION METHOD (S.C.C.M.) APPLIED TO IDEAL ISING AND HEISENBERG MAGNETIC SYSTEMS by P.C. Clapp (Ledgmont Lab., Kennecott Copper); J. Appl. Phys., Vol. 35, p. 947, Mar. 196

The theory described is classified as a cluster theory of ferromagnetism. It is presently restricted to lattices with nearest-neighbor interactions, but unrestricted in spin magnitude. The point of departure from previous cluster theories is that it represents the effect of the other spins of the lattice on the cluster as a temperature-dependent exchange coupling, rather than as a molecular field. A second significant departure is to impose a consistency condition on the spin-spin correlation functions of the cluster rather than on the spin averages. The cluster chosen for application of the theory consists of a central spin pair plus the additional spins and bonds necessary to form all the next most direct linkee paths between the central spin pair. In the cluster Hamiltonian the central coupling has the constant value J while all the other couplings are taken to have a temperature-dependent value J'(T) which will be evaluated self-consistently. J'(T) can be understood physically as the direct coupling J plus an additional coupling caused by the correlative effect of spins outside the cluste acting on the cluster spins. The S.C.C.M. Hamiltonian can be derived by writing the density matrix for the entire spin system and formally summing over all spin variables except those of the cluster. From this reduced density matrix it is possible to infer the form of the corresponding Hamiltonian. Apart from small terms which vanish at high temperatures, this is the S.C.C.M. Hamiltonian. By demanding that the correlation between the central pair be equal to that of any other nearest neighbor pair, J(T) can be uniquely determined for any temperature. The average energy, the free energy, and the specific heat of the lattice are immediately obtainable from the cluster calculation. If the correlation function is calculated with an external magnetic field added, then the dc magnetic susceptibility and average magnetization can also be determined.

24,135 REMARKS ON THE OGUCHI TRANSFORMATION by R.A. Tahir-Kheli and H.B. Callen (U. Pennsylvania); J. Appl. Phys., Vol. 35, pp. 948-949, Mar. 1964

s shown that the Oguchi transformation in the theory of ferromagnetism is a
w-temperature spin-wave approximation, whose validity depends on the im-
cit assumption that the kinematical interaction can be ignored. This limita-
n has the consequence that the theory of Oguchi and Honma, if accepted at
her temperatures, predicts an infinite Curie temperature.

,136 TIME-DEPENDENT CORRELATIONS IN A SOLVABLE FERROMAG-
TIC MODEL by N.D. Mermin (U. California, San Diego); Phys. Rev., Vol.
1A, pp. A112-125, Apr. 6, 1964

e exact equation of state, two-time correlation function, and linear response
ction, are calculated in the limit of infinite N for a classical N-spin system
h a ferromagnetic phase transition, in a particular nonuniform magnetic field.
e correlation function can be analytically continued in temperature (or mag-
ic-field strength) from the nonferromagnetic to the ferromagnetic region of
T-H plane; the result of such continuation is not, however, the correlation
ction for the ferromagnetic region, but a function which grows exponentially
time. The frequency-dependent linear response function has a pole at zero
quency throughout the ferromagnetic region due to a broken symmetry; the
responding function in the nonferromagnetic region develops a pole at zero
quency as the ferromagnetic region is approached, but when the function is
ntinued in temperature (or field strength) into the ferromagnetic region, the
e detaches itself from the origin and moves up into the complex frequency
ne, signifying an exponential growth in time of the linear response. The
pose of the model is to demonstrate that this kind of behavior does not con-
dict any general structural properties of equilibrium thermodynamic correla-
n or response functions. The possible general significance of such behavior
a theory of metastable states is discussed.

,137 DERIVATION OF THE MODIFIED BLOCH EQUATIONS FOR SPIN
STEMS by J. Korringa and J.-L. Motchane (Fac. Sci., Besancon, France),
Papon (Fac. Sci., Paris), and A. Yoshimori (Nagoya U., Japan); Phys. Rev.,
l. 133A, pp. A1230-1234, Mar. 2, 1964

new form of the equations for the time-dependent statistical matrix of a spin
tem is used to derive the modified Bloch equations, without considering de-
ls of the relaxation mechanism. A number of restrictive conditions are im-
sed on the system, most of which agree well with known limitations of the
plicability of the modified Bloch equations. In order to avoid complications,
ly spins one-half are considered. The theory does not apply to the case where
e relaxation is anisotropic but where the constant field and an applied rotat-
g field are comparable in magnitude.

,138 SPECIFIC HEAT AND LONGITUDINAL CORRELATION FUNCTION
R THE HEISENBERG FERROMAGNET by R.A. Tahir-Kheli and H.B. Callen
. Pennsylvania); J. Appl. Phys., Vol. 35, pp. 946-947, Mar. 1964

e correlation function of the z components of the spins in a ferromagnet is
lculated as a function of the interspin distance, temperature, and applied
gnetic field. The formalism used is that of two-time, temperature-depend-
t Green functions, with the decoupling approximation introduced by Callen.
e results accordingly agree with those obtained by spin-wave theory at low
mperatures, and remain approximately valid up to the region of the Curie
mperature. Knowledge of the correlation function for nearest neighbors en-
les one to calculate the energy and thence the specific heat; the results are
so relevant to elastic neutron scattering.

,139 EFFECT OF MAGNETIC ANISOTROPY ON THE SPIN-WAVE SPEC-
UM by H.C. Mang (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5,
. 1169-1174, Dec. 1963

eneral expressions are derived for the spectrum of a spin-wave ellipsoid in a
bic and uniaxial ferromagnetic crystal, including mechanical stresses. It is
own that the magnetostriction constants λ_{100} and λ_{111} of a cubic crystal may
e measured simultaneously on the same sample under constant applied uniaxial
mpression or tension.

4,140 AN ANALOG COMPUTER STUDY OF UNSTABLE SPIN WAVES by F.
. Morgenthaler (MIT); J. Appl. Phys., Vol. 35, pp. 900-901, Mar. 1964

sults concerning second-order instabilities of spin waves obtained by analog
mputation are presented. In addition to the direct information they provide,
ne of the great virtues of the computer results is to indicate forms of solutions
at are possible. For example, an interesting "capture" phenomenon, whereby
e uniform precession forces certain spin waves into phase synchronization and
ence unstable growth, once discovered, can be understood by inspection of
e equations. The presence of certain relaxation oscillations can be explained
t least qualitatively.

4,141 COMPUTER STUDY OF TRANSIENT SPIN-WAVE BUILDUP IN FER-
ITES by K.J. Harker and H.J. Shaw (Stanford U.); J. Appl. Phys., Vol. 35,
p. 902-903, Mar. 1964

he equations of motion for spin waves in a spherical ferrite sample, together with equations for the uniform mode, have been programmed on a digital computer. The equations for the uniform mode are general and allow for arbitrary amplitude of the mode. The spin-wave equations are solved to first order in the spin-wave amplitudes, so that the parametric couplings which lead to first-order and second-order spin-wave instabilities are included. These equations have been solved for the case of transient buildup of the uniform mode in a magnetic field whose amplitude rises linearly with time. With rapidly rising fields, it is found that the uniform mode attains amplitudes far exceeding the limits of the usual small-signal analysis. The parametric buildup of spin waves accompanying the uniform mode is traced as a function of time, and the effect of these spin waves upon the uniform mode is considered. This defines the conditions under which useful transient devices can be designed for the generation of microwave energy with pulsed magnetic fields, which can take advantage of the large RF magnetization in ferrites when operated well beyond the usual steady-state saturation limits.

24,142 SPIN-WAVE RENORMALIZATION APPLIED TO FERROMAGNETIC $CrBr_3$ by H.L. Davis and A. Narath (Sandia Lab.); Phys. Rev., Vol. 134A, pp. A433-441, Apr. 20, 1964

Nuclear-magnetic-resonance-domain magnetization data for ferromagnetic $CrBr_3$ have been extended over the range 1-20°K. Using the low-temperature (≤ 5.25°K) data and Holstein-Primakoff spin-wave theory without the usual long-wavelength approximation the exchange constants reported by Gossard, Jaccarino, and Remeika are shown to be in error by about 40 per cent. This error resulted from the long-wavelength approximation, which causes, even at temperatures 1/9th the Curie temperature, errors much larger than experimental errors. In the low-temperature range, a 20 per cent range for the values of the exchange constants which will explain the experimental results was found. However, by using spin-wave renormalization techniques to interpret the intermediate temperature data, the acceptable range in values for the exchange constants is narrowed to less than 2 per cent. The experimental NMR frequencies, throughout the temperature range of 1-20°K can be fitted, with the renormalized spin-wave theory. The resulting rms error of 16,2 kc/sec lies within the mean experimental error, thereby giving experimental verification to the approximations used in developing the spin-wave renormalization. This data fit gives 8.25°K for the intralayer exchange constant, 0.497°K for the interlayer exchange constant, and 58.099 Mc/sec for the 0°K, zero-field Cr^{53} resonance frequency.

24,143 SOME CONSIDERATIONS ON THE MAGNETIC CARRIERS IN FERROMAGNETIC TRANSITION METALS by T. Izuyama (MIT) and R. Kubo (U. Pennsylvania); J. Appl. Phys., Vol. 35, pp. 1074-1081, Mar. 1964

Some properties of itinerant electron ferromagnets are examined theoretically on the basis of a simple model in which the electron Coulomb interaction is assumed to be effective only in an atomic cell. Results of a previous study on the neutron diffraction phenomena are briefly reviewed. An itinerant electron model seems to be capable of accounting for almost all features such as diffuse scattering, critical scattering, and paramagnetic scattering. It is emphasized that the spin-wave modes play very important roles. The study is extended to the low-temperature behavior of spin waves. Unlike the spin waves in a Heisenberg model, the spin-wave frequency in metallic ferromagnets has a T^2 term in its temperature dependence. This is shown by a phenomenological consideration and also by explicit calculations on a s-d model and an itinerant electron model. Finally it is pointed out that the specific heat of the simple itinerant model has a singularity of $(T - T_c)^{-1/2}$ around the Curie point.

24,144 EXPERIMENTAL STUDIES OF STANDING SPIN-WAVE MODES IN FERROMAGNETIC FILMS by M. Nisenoff and R.W. Terhune (Ford Motor); J. Appl. Phys., Vol. 35, pp. 806-807, Mar. 1964

Standing spin-wave mode measurements have been made on thin films of Permalloy, cobalt, and iron using microwave frequencies between 9.8 and 32 Gc/sec. Clear experimental evidence has been obtained for the existence of the theoretically predicted k^2 dependence of the magnetic field spacings with the magnetic field both parallel and normal to the plane of the film. In most of these films, deviations from the k^2 law were observed for low-order spin waves with the applied field normal to the plane of the film. In this region, the dependence ranged from near quadratic to linear and a distinctly different intensity variation for the lines was observed. With the applied field in the plane of the film, for thickness d less than 1200 A, the intensity behavior of the higher-order modes increased very rapidly with microwave frequency. The pinning conditions for the standing spin waves deduced from these observations can be qualitatively explained by assuming that the RF magnetization at an air interface is completely unpinned and that the film has surface layers of lower magnetization than the bulk.

24,145 SPIN-WAVE ENERGIES AND EXCHANGE PARAMETERS IN IRON-NICKEL ALLOYS by M. Hatherly, K. Hirakawa, R.D. Lowde, J.F. Mallett, M.W. Stringfellow and B.H. Torrie (AE Res. Estab., Harwell); J. Appl. Phys., Vol. 35, p. 802, Mar. 1964

The energies of long-wavelength spin waves in iron-nickel alloys have been

measured as a function of composition by a neutron small-angle-scattering technique. The behavior of the composition dependence can be explained in terms of a simple model invoking long-range interaction functions $\mathcal{J}(r)$ between the three different types of atom pair: Fe-Fe; Fe-Ni; and Ni-Ni. There is evidence that on the bcc lattice the iron-nickel interaction $\mathcal{J}(r)$ changes sign from +ve to -ve as a function of distance. Between Fe-Fe pairs on a fcc lattice, the "exchange integral" as normally defined is -8 ± 2 Mev, consistent with other indications that fcc iron is antiferromagnetic.

MAGNETIZATION

24,146 MAGNETIZATION OF THIN FERROMAGNETIC FILMS AT LOW TEMPERATURES by V. Ya. Demikhovskii and B.A. Tavger (Gor'kii State U.); Soviet Phys.-JETP, Vol. 18, pp. 797-798, Mar. 1964

Ferromagnetism in thin films is treated on the basis of spin-wave theory. Because of the quantization of the quasimomentum perpendicular to the plane of the films, a gap appears in the energy spectrum of the ferromagnons. Taking the quantization into account leads to an exponential dependence of the magnetization on temperature in the low-temperature region. Results of numerical calculations of the dependence of the magnetization on temperature and on film thickness are presented.

24,147 THE DYNAMIC BEHAVIOR OF MAGNETIC THIN FILMS by B.R. Hearn (Mullard Res. Lab.); J. Electronics and Control, Vol. 16, pp. 33-57, Jan. 1964

The effective damping constant λ_{eff} has been measured as a function of frequency by UHF ferromagnetic resonance. The results are compared with those obtained by using a small angle free oscillations technique. In addition, both methods offer a means of determining the gyromagnetic ratio γ. The damping factor λ_{eff} is measured as a function of the anisotropy field H_K, and also of the composition of the nickel-iron film. A possible dispersion of λ_{eff} within the film is discussed. λ_{eff} is also deduced from the exponential decay times of the damped oscillations which occur in experimental hard direction switching waveforms. Such waveforms agree qualitatively with coherent rotational theory. Experimental switching waveforms obtained with large amplitude pulsed reversing fields, applied at 135° to the easy direction, also agree qualitatively with theoretical predictions. Small observed deviations from theory are, perhaps, related to local inhomogeneities of both the anisotropy field and the easy direction. For 135° switching with lower fields, the rotation is incoherent, probably on account of the same inhomogeneities. Switching threshold curves are measured, and these differ markedly from the theoretical astroid stability diagram, because of the disturbing influences of domain switching and incoherent rotation.

Magnetization of Ni-Fe Films - See 24,203

24,148 EFFECT OF NONUNIFORM MAGNETIZATION ON THE SPIN-WAVE SPECTRUM IN THIN FERROMAGNETIC FILMS by J.T. Davies (U. Pittsburgh); J. Appl. Phys., Vol. 35, pp. 804-805, Mar. 1964

It was first suggested by Portis that the linear positioning of the first few spin-wave modes observed in some ferromagnetic films could be due to a nonuniform static magnetization M and he examined a simple model which showed this effect. This model, where the magnetization falls parabolically from the film center, has been studied in greater detail. The modes found by Portis are incorrect in detail, since they all collapse onto the uniform mode as the distortion of M goes to zero. A more suitable choice of boundary conditions gives rise to a spectrum where the lower modes are linearly positioned whereas the higher modes tend to the more usual quadratic positioning. For a given relative distortion, the number of linear modes should be greater the thicker the film. This is in agreement with the measurements of Kooi, Wigen, and Nisenoff on Permalloy films, though the transition between linear and quadratic positioning observed by Nisenoff is much more abrupt than this model predicts.

24,149 INFLUENCE OF THE THERMAL AND MECHANICAL HISTORY ON THE SQUARENESS CHARACTERISTICS OF 4-79 MOLYBDENUM PERMALLOY by G.Y. Chin, L.L. Vanskike and H.L. Andrews (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 867-869, Mar. 1964

A correlation has been obtained between crystallographic texture and the squareness characteristics of 4-79 molybdenum Permalloy wire and tape. When cold drawn (99% RA) 2.18-mil-diam Permalloy wire was annealed at 800°C for 0-7.8 sec, 60 cps B_r/B_s values (measured along the wire axis) dropped from 0.95 to 0.70. Further drawing of the annealed wires to 1.3 mil resulted in an increase of B_r/B_s, relative to the 2.18-mil wire, for the short-anneal (0.31 and 0.65 sec) samples and a decrease for the long-anneal (0.3 and 7.8 sec) samples. The trend was reversed when the 1.3-mil wires were roll flattened to tapes such that the direction of flow was perpendicular to the wire axis. X-ray studies indicated a strong <111> fiber texture in the cold-drawn wire and a <100>+<111> double texture after annealing, the ratio of <100> to <111> intensity increasing with annealing time. The tapes contained (100)[001] and $(1\bar{1}0)[111]$ 6° texture components, the intensities of which were related, respectively, to those of <100> and <111> components in the original wire. Thus it appears that drawing of a <111> wire led to increased squareness, in contrast to the <100> case; the reverse behavior, however, was exhibited in tapes rolled flattened from wires of these two textures.

24,150 PRESSURE DEPENDENCE OF THE MAGNETIZATION OF COBALT J.S. Kouvel and C.C. Hartelius (GE Res. Labs.); J. Appl. Phys., Vol. 35, 940-941, Mar. 1964

Single-crystal and polycrystalline specimens of cobalt were subjected at room temperature to hydrostatic pressures up to about 5 kbars, and the effects on their magnetizations were measured in fields up to 14 koe. For the single crystal magnetized along its easy axis, complete saturation was achieved at about 3 koe, and above this field the pressure dependence of the magnetization (per g) remained constant at a saturation value, $\sigma_s^{-1}(\partial\sigma_s/\partial p)$, of -2.18×10^{-4} $kbars^{-1}$. This value is shown to be identifiable with the pressure dependence of the atomic moment at 0°K and has the same sign and even roughly the same magnitude as the recent low-temperature pressure results for iron and nickel. For the cobalt polycrystal, the change in magnetization with pressure varied widely (though smoothly) with field before attaining the above saturation value at about 13 koe. The lack of saturation at lower fields was attributed entirely to magnetocrystalline anisotropy, and a graphical integration method applied to the data gave the result: $K^{-1}(\partial K/\partial p) = -23.2 \times 10^{-4} kbars^{-1}$, where K is the total anisotropy energy (per g) and is linearly related to the anisotropy coefficients, K_1 and K_2. The similarity in sign and the order of magnitude difference between the $K^{-1}(\partial K/\partial p)$ and $\sigma_s^{-1}(\partial\sigma_s/\partial p)$ values for cobalt are closely analogous to the situation previously found in iron and an iron-silicon alloy.

24,151 EFFECT OF LATTICE DEFECTS ON THE MAGNETIZATION CURVE OF FERROMAGNETS by A. Seeger, H. Kronmuller, H. Rieger and H. Trauble (Tech. Hoch., Stuttgart); J. Appl. Phys., Vol. 35, pp. 740-748, Mar. 1964

A theoretical treatment of the action of internal stresses on domain walls and on uniformly magnetized Weiss domains is presented. The theory is based on micromagnetics, dislocation theory, and probability theory. Experimental results on the domain structure, the temperature dependence of the reversible susceptibility, and the coercive field of plastically deformed nickel, cobalt, and silicon-iron single crystals and neutron-irradiated nickel single crystals are discussed on the basis of the theory. The experiments are interpreted in terms of the magneto-elastic interaction between dislocations and magnetization and agree satisfactorily with the theoretical predictions. The observed variations of the domain structure during the magnetization process can be accounted for in terms of the theory of phases (Néel, Lawton, and Stewart) and the mobility of the domain walls.

24,152 STUDIES OF THE OPTICS OF NEUTRONS. Part IV. MAGNETIC SATURATION AND NEUTRON DEPOLARIZATION by O. Halpern (Pacific Palisades, Calif.); Phys. Rev., Vol. 134A, pp. A126-127, Apr. 6, 1964

It is suggested that the magnetic saturation of ferromagnets should be studied a slight modification of the previously used method. Instead of measuring the retardation of the single transmission effect in incompletely saturated ferromagnets as a function of the magnetizing field, it is recommended to study the depolarization of a totally polarized beam passing through a ferromagnet. This study would be carried out by a measurement of the polarization of the transmitted beam and no longer by an intensity measurement.

24,153 EFFECT OF SHORT-RANGE ORDER ON THE MAGNETIC PROPERTIES OF FERRITES WITH A GARNET-TYPE STRUCTURE by A.N. Men', V.P. Polyakov, G.A. Smolenskii and G.I. Chufarov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 937-939, Nov. 1963

Using Gilleo's scheme, the effect of short-range order on the saturation magnetization of solid solutions of garnets containing nonmagnetic ions in tetrahedral and octahedral sites is discussed. A comparison of the theory with experiment is made for the solid solution $(1-x)Y_3Fe_5O_{12}-xCa_3Fe_2Si_3O_{12}$. It is shown that in theory there are two parameters relating the pair interaction energies and they can be determined by comparing theory with experiment.

24,154 ABOUT THE ΔI_s EFFECT DURING PLASTIC DEFORMATION OF FERROMAGNETS by I. Ya. Dekhtyar and D.A. Levina (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1987-1989(L), Mar. 1964

The effect of plastic deformation on the saturation magnetization I_s of ferromagnets is discussed. It is shown that in the first approximation the effect is proportional to the dislocation density, and at high temperatures it is greater for ferromagnets with lower Curie temperature. The percentage change of the saturation magnetization $\Delta I_s/I_s$ was estimated for the Invar alloys, and it was found that $\Delta I_s/I_s = 4$ per cent, which agrees qualitatively with experiment.

24,155 TEMPERATURE DEPENDENCE OF THE SUBLATTICE MAGNETIZATION IN FERRIMAGNETIC $MnFe_2O_4$ by A.J. Heeger and T. Houston (U. Penn.); J. Appl. Phys., Vol. 35, pp. 836-837, Mar. 1964

The temperature dependence of the A-site sublattice magnetization in ferrimag-

ic $MnFe_2O_4$ has been measured by observing the temperature dependence of Mn^{55} NMR frequency. The initial deviation from saturation is proportional $T^{3/2}$ but no $T^{5/2}$ term is observed. These results are found in agreement with errimagnetic spin-wave calculation for the spinel lattice. Two $T^{5/2}$ terms of posite sign originate from the k^4 terms of the dispersion relation and the k-pendent transformation coefficients from single sublattice spin-deviation op-tors to the diagonal spin-wave variables. These two terms cancel, for the nel lattice, to within 1 per cent.

,156 THE MAGNETIC AFTER-EFFECT IN PURE IRON AT ELEVATED TEM-RATURES by L. Alberts, W.P. Van Ryneveld and P.E. Viljoen (U. Orange e State, Bloemfontein); Nuovo Cimento, Vol. 32, pp. 64-70, Apr. 1, 1964

a time decrease in the permeability of pure iron was studied as it occurs in temperature range 120°C to 750°C. Experimental results indicate that the bilization of the Bloch walls could be due to the movement of dislocations positions of lower energy in the vicinity of the walls. Satisfactory agreement obtained between the experimental value for the viscosity field at a given nperature and a value as calculated on the basis of a dislocation model by rci, Ferro and Montalenti. The results also indicate that at this temperature initial magnetization process is virtually entirely due to the movement of 0° walls.

,157 OBSERVATIONS OF THE ORDERING PROCESS IN A Mg-Fe FERRITE C. Heck and G. Vaccari (Standard Elek. Lorenz AG); J. Appl. Phys., Vol. , pp. 907-909, Mar. 1964

owly cooled magnesium-iron ferrites ($MgO2FeO \cdot 4Fe_2O_3$) have constricted steresis loops in a wide range of temperature. Applying a magnetothermic atment, an anisotropy which is accompanied by a square hysteresis loop can induced. The speed of the ordering process can be varied in a certain range variation of the temperature. During the conversion of the shape of the hys-esis loop the remanence ratio B_r/B_m increases. An activation energy of 0.37 can be derived from the temperature dependence. The peak induction in-eases with time discontinuously in two main steps while the field is kept con-nt. The time at which the steps occur varies with temperature. An activa-n energy of 1.4 ev can be derived. Nearly the same value was calculated m the temperature dependence of an observed minimum of the magnetization ergy occurring during loop transformation. The depth of this minimum can be ken as a measure of the induced anisotropy.

,158 SUBLATTICE MAGNETIZATION AND LATTICE DISTORTIONS IN nO AND NiO by D.S. Rodbell and J. Owen (GE Res. Lab.); J. Appl. Phys., l. 35, pp. 1002-1003, Mar. 1964

in the Heisenberg interaction $J(\bar{S}_a \cdot \bar{S}_b)$, J is separation dependent and the ttice is distortable, then an extended system of arbitrary angular momentum elds more long-range order at a given temperature than the molecular field edicts for the "clamped crystal." Both MnO and NiO show such departures m molecular field prediction and earlier estimates based on isotropic defor-ations could not account for the observed behavior. Anisotropic deformations ve not previously been considered in this regard. The form of these anisotrop-distortions is a contraction along the [111] crystallographic direction perpen-cular to the sublattice magnetization. In NiO this trigonal deformation cor-sponds to a change in angle of the original cubic cell from 90° to 90°06'. is distortion accounts for only a small part of the sublattice magnetization's viation from molecular field prediction. For MnO, on the other hand, neu-on diffraction data indicate that this angle is as large as 90°26', a distortion at would account for about a third of the observed estimate. A direct X-ray ffraction measurement of this deformation fully confirms this value. The X-y data supply additional evidence that the disordering transition in MnO is ermodynamically of first order.

4,159 MAGNETIZATION OF PERMALLOY AT LOW TEMPERATURES by B.E. rgyle and S.H. Charap (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 02-803, Mar. 1964

yromagnetic measurements of the magnetization of a single-crystal sphere at rmalloy (79.65 Ni-20.35 Fe by weight) in the range 4.2°-100°K and with pplied fields of 4, 9, and 14 koe parallel to the [111] crystal axis are reported nd interpreted in terms of spin-wave theory. The spin-wave energy gap obeys e theoretical expression in terms of internal applied field, magnetocrystalline nisotropy field (negligible), and average spin-wave demagnetizing field. The oefficients appropriate to zero gap are $C = (7.6 \pm 0.1) \times 10^{-6}$ deg$^{-3/2}$ for the $^{3/2}$ term and $D/C \leq \pm 0.2 \times 10^{-3}$ deg^{-1} for the $T^{5/2}$ term. The analysis of the ata is made using a new graphical method which displays visually the quality f fit to the theory. The C value implies $(JS)_{eff}/k_B = 134°K$ in good agreement ith independent determinations of the spin-wave dispersion parameter.

4,160 MAGNETIC PROPERTIES OF CUPRON WIRE AT LOW TEMPERATURES y E. Lerner, M. Wilson, J. Gaines and J. Daunt (Ohio State U.); Rev. Sci. nstr., Vol. 35, p. 117(L), Jan. 1964

he magnetization of Cupron wires has been measured in the temperature range to 100°K. The remanent magnetization became nearly independent of temperature and fell to zero at 57.5°K, indicating a transition from ferromagnetism to paramagnetism which is unsuitable for use in low temperature equipment designed for magnetic studies.

24,161 INVESTIGATION OF THE MAGNETIZATION OF A FERRITE GARNET IN STRONG PULSED MAGNETIC FIELDS by V.E. Rode and A.V. Vedyaev (Moscow State U.); Soviet Phys.-JETP, Vol. 18, pp. 286-287, Feb. 1964

An investigation of the magnetization of gadolinium garnet in a pulsed magnetic field of up to 200 koe at room temperature is reported. It is found that the ferrite sublattices rotate in sufficiently strong fields and consequently the total magnetic moment of the sample increases considerably. The parameter of the exchange interaction between Gd and Fe sublattices and the effective field acting on the gadolinium sublattice are found to be $\Theta_{12} = 23 \pm 4°K$ and $H_{eff} = (2 \pm 0.4) \times 10^5$ oe, respectively.

24,162 MAGNETIZATION OF GADOLINIUM NEAR ITS CURIE TEMPERATURE by F.J. Darnell and W.H. Cloud (du Pont); J. Appl. Phys., Vol. 35, pp. 935-936, Mar. 1964

Magnetization measurements on single crystals of gadolinium yield a Curie temperature of 290±1°K, determined by a plot of M^2 vs H/M. Measurements of magnetization vs applied field extrapolated to zero field show appreciable magnetic order above this temperature. X-ray lattice parameter measurements on the same crystals allow estimation of magnetization in zero field and confirm the presence of magnetic order up to ~305°. The zero field moment at 290°, $M(T = 290°)/M(T = 0°)$, is estimated from lattice expansion to be 0.3, compared to a value of 0.2 obtained from the extrapolated magnetization measurements.

24,163 THE MAGNETIZATION OF FACE CENTERED CUBIC IRON-NICKEL ALLOYS IN THE VICINITY OF INVAR REGION by Y. Bando (Kyoto U.); J. Phys. Soc. Japan, Vol. 19, p. 237(L), Feb. 1964

Magnetization as a function of composition in fcc Fe-Ni alloys powder of about 0.4 μ particle size is described. Data on spontaneous magnetization at absolute zero and calculated magneton numbers for different compositions confirm earlier expectation that the saturation magnetization of the alloys would decrease abruptly in the neighborhood of 30 per cent nickel.

24,164 TEMPERATURE DEPENDENCE OF MAGNETIZATION ON HEATING AND COOLING OF LITHIUM FERRITE-CHROMITE IN WEAK MAGNETIC FIELDS by A.I. Drokin, R.P. Smolin and L.I. Ryabinkina (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1502-1505, Feb. 1964

A study of the temperature-dependent magnetic hysteresis and electrical resistivity of a lithium ferrite-chromite in the temperature range from 20°C to the Curie point is reported. It is found that the curves of the temperature dependence of the magnetization contain characteristic peculiarities which clearly emphasize the two-sublattice structure of the ferrite, and two compensation points can be obtained under certain conditions.

24,165 EXPERIMENTAL DETERMINATION OF PERMEABILITY-STRESS RELATIONSHIPS by L.I. Mendelsohn, E.D. Orth and P.A. Robbins (GE Instr. Dep.); J. Appl. Phys., Vol. 35, pp. 863-865, Mar. 1964

Large variations in permeability are probable in most soft ferromagnetic materials subjected to stress. The magnitude of these variations depends on the direction between the applied magnetizing force and the stress. Techniques are described for measuring the ac permeability under two different stress conditions. $\mu_{||}$ symbolizes the permeability when magnetizing force and induction are both parallel to the applied stress; $\mu_{\perp}$ when they are both perpendicular to it. Of the materials investigated, those which have positive magnetostrictive coefficients show their maximum permeability change when magnetizing force and stress are at right angles to one another. For nickel, which exhibits negative magnetostriction, the maximum permeability change occurs when magnetization and stress are collinear. Permeability values, $\mu_{||}$ and $\mu_{\perp}$, for ingot iron, nickel, Nicaloi, and Hy-mu 80 are tabulated after the first stress cycle from 0 to 12,000 psi (850 kg/cm^2), and at zero stress after two additional cycles. The difficulty with predicting permeability changes from magnetostriction concepts alone is exemplified by Hy-mu 80, a 79 per cent Ni-17 per cent Fe-4 per cent Mo alloy, which has a low magnetostrictive coefficient. Based on this fact alone one would not predict the variations observed in $\mu_{\perp}$ from 14,000 at zero stress to 3800 at 12,000 psi.

24,166 EFFECT OF PRESSURE ON THE CURIE TEMPERATURE OF RARE-EARTH METALS. Part I. GADOLINIUM by L.B. Robinson, F. Milstein, and J. Jayaraman (U. California, Los Angeles); Phys.Rev., Vol. 134A, pp. A187-192, Apr. 6, 1964

An experimental investigation has been undertaken for the purpose of learning the effect of interatomic distance on the magnetic exchange interaction in ferromagnetic rare-earth metals. The first material which has been studied is gadolinium. A toroidal-shaped specimen of gadolinium was subjected to pressures up to about 40 kbars. The gadolinium toroid served as a transformer core. A

constant input voltage was applied and the output voltage was studied as a function of pressure and temperature. The Curie temperature, obtained from the output voltage, was found to be depressed linearly with pressure at a rate of -1.60°C/(kbar) up to 21.5 kbar. Between 21.5 and 26.7 kbar a phase transition to a nonferromagnetic state occurred.

24,167 IMPORTANCE OF INTRASUBLATTICE MAGNETIC INTERACTIONS AND OF SUBSTITUTIONAL ION TYPE IN THE BEHAVIOR OF SUBSTITUTED YTTRIUM IRON GARNETS by S. Geller, H.J. Williams, G.P. Espinosa and R.C. Sherwood (Bell Labs.); Bell Sys. Tech. J., Vol. 43, pp. 565-623, Mar. 1964

The results of measurements at moderate to high magnetic fields on a large number of nonmagnetic ion substituted yttrium iron garnets suggest that intrasublattice interactions play an important role in determining their spontaneous magnetizations and Curie temperatures. It is shown that the system $\{Y_{3-x}Ca_x\}[Fe_2]-(Fe_{3-x}Si_x)O_{12}$ is continuously related to the system $\{Y_{3-x}Ca_x\}[Zr_xFe_{2-x}](Fe_2)O_{12}$ or $\{Y_3\}[Sc_xFe_{2-x}](Fe_3)O_{12}$. It is concluded that in these systems the tetrahedral-tetrahedral (d-d) antiferromagnetic interactions are stronger than octahedral-octahedral (a-a) antiferromagnetic interactions. The changes in magnetic structure from an ideal ferrimagnetic, yttrium iron garnet, to an end-member in which there are at least short-range antiferromagnetic interactions (i.e., in $\{Ca_3\}[Fe_2](Si_3)O_{12}$ or a hypothetical $\{YCa_2\}[Zr_2](Fe_3)O_{12}$) should bear an analogy to the crystal chemical changes. It is therefore proposed that when substitution is made exclusively in one sublattice, the moments of the Fe^{3+} ions in that sublattice remain parallel (as in the Yafet-Kittel theory), while the weakened average a-d interactions and the intrasublattice interactions lead to random canting of the Fe^{3+} ion moments of the other. This tendency occurs as soon as substitution begins. On continued substitution, a point is reached beyond which canting increases much more rapidly with increasing substitution. In this region, the intrasublattice interactions dominate the a-d interactions, but it is probable that the canting continues to be random.

24,168 DIFFERENTIAL THERMAL ANALYSIS AND MÖSSBAUER STUDIES IN RARE-EARTH ORTHOFERRITES by M. Eibschutz, G. Gorodetsky, S. Shtrikman and D. Treves (Weizmann Inst. Sci., Rehovoth, Israel); J. Appl. Phys., Vol.35, pp. 1071-1072, Mar. 1964

Curie temperatures of 14 different orthoferrites with the chemical formula $RFeO_3$, (R = Y, La, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb, Lu) were measured by differential thermal analysis. Hyperfine interactions of the Fe^{57} nucleus in the same materials were determined from their Mössbauer spectra. The quadrupole splittings (except for Sm), isomer shifts, Curie temperatures, and internal fields vary regularly with the ionic radius of R.

24,169 MAGNETIC PROPERTIES OF COBALT-SUBSTITUTED Ni-Zn FERRITES by M. Mizushima (Sony Corp.); Japanese J. Appl. Phys., Vol. 3, pp. 82-86, Feb. 1964

The imaginary part μ'' of the complex magnetic permeability $\hat{\mu}$ ($\hat{\mu} = \mu' - j\mu''$) was found to be linearly related to the real part μ' for cobalt-substituted ferrites with the same composition which were annealed at 280°C for various periods. This fact is explained by assuming that the imaginary part is associated with wall displacement and the contribution of this process to μ' is related to the value of induced anisotropy which is different among specimens heat-treated differently. Two peaks of the imaginary part μ'' were observed in magnetic spectra for the AC demagnetized specimens. The low frequency peak is ascribed to the resonance of domain walls which were displaced from their stable positions. Abrupt increase of the imaginary part μ'' and disappearance of constricted loops were observed at low temperatures, which are explained in terms of the change in sign of the cubic crystalline anisotropy constant K_1.

24,170 NATURAL SPECTRUM OF POLYCRYSTALLINE YIG AS A FUNCTION OF DENSITY by J.D. Holm and A.H. Morrish (U. Minnesota); J. Appl. Phys., Vol. 35, pp. 894-895, Mar. 1964

The initial permeability of polycrystalline yttrium iron garnet has been measured as a function of density at frequencies from 5 kc/sec to 7.5 Gc/sec. The samples were prepared by grinding very pure single crystals into a powder and then pressing and sintering. The samples of highest density have two absorption peaks that occur at approximately 1 Mc/sec and 200 Mc/sec. This is in very good agreement with observations on polycrystalline samples prepared with coprecipated powders but not with those prepared with raw oxides. The separation between the two absorption peaks decreases as the sample density decreases, until ultimately only one peak is observed in a sample with 72 per cent density. The results are interpreted in terms of the changing sample porosity.

24,171 INITIAL SUSCEPTIBILITY OF FERROMAGNETIC IRON AND IRON-VANADIUM ALLOYS JUST ABOVE THEIR CURIE TEMPERATURES by J.E. Noakes and A. Arrott (Ford Motor); J. Appl. Phys., Vol. 35, pp. 931-932, Mar. 1964

Induction measurements of magnetization of spherical samples of Fe and Fe(V) alloys in low applied fields are used to deduce the temperature dependence of initial susceptibility near the critical temperature. The initial susceptibility follows an expression of the form $\chi = A(T-T_c)^{-\gamma}$, where T_c is the Curie temperature. The value of γ for Fe is 1.37 ± 0.04. In dilute Fe(V) alloys γ decreases with increasing concentration of solute.

24,172 MAGNETIZATION CURLING IN TAPERED EDGE FILMS by R.M. Hornreich (LFE); J. Appl. Phys., Vol. 35, pp. 816-817, Mar. 1964

A 90° curling of the magnetization occurs at those film edges perpendicular to the easy axis in films of 700-1800 A thickness when the film edges are suitably tapered. This configuration replaces the closure domain state generally found at the edges of films in this thickness range. Theoretical calculations yield expressions for the preferred edge taper angle and the resultant distance in which the magnetization curling takes place. The expressions for the edge taper angle and the curling distance are given in terms of the anisotropy, exchange, and magnetization constants and the film thickness. The curling distances that occur in actual films are measured and found to be in good agreement with the theoretical predictions. Experiments showing the differences in switching behavior of tapered and nontapered films are described and correlated with theory.

24,173 MECHANISM OF RIPPLE FORMATION IN THIN FILMS by R.J. Spain and I.B. Puchalska (LFE); J. Appl. Phys., Vol. 35, pp. 824-825, Mar. 1964

To test the hypothesis that magnetization ripple in thin films is due to the random oriented magnetocrystalline anisotropies of the individual crystallites, highly oriented iron films have been made which exhibit a marked decrease in ripple intensity. Changes in ripple intensity, produced by applying mechanical stresses so as to vary the resultant uniaxial anisotropy constant of a given sample, are consistent with the model of variations of the local easy axis direction as responsible for the formation of magnetization ripple.

24,174 ESTABLISHMENT OF MAGNETIZATION PRECESSION OF FERRITES AT HIGH POWER LEVELS by A.P. Aleksandrov, G.M. Genkin, G.L. Gurevich and V.I. Dubinin (Gor'kov State U.); Soviet Phys.-Solid State, Vol. 5, pp. 2024-2027, Apr. 1964

A study of the time dependence of the transverse magnetization component of yttrium ferrogarnet at the natural resonance as a function of an exciting alternating magnetic field h and a constant magnetic field H_0 is reported. The precession was excited in the ferrite with UHF square pulses. At high power levels the form of the signal emitted is observed to change appreciably as a function of h and H_0. It is concluded that in a certain range of h and H_0, a constant value of $M_\perp$, corresponding to the excitation field, is not established along the entire length of the excitation pulse.

24,175 MAGNETIZATION REVERSAL IN WEAK FERROMAGNETS by R.J. Joenk (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 919-920, Mar.19

The critical values of the applied field for reversal of the magnetization and the corresponding initial modes of deviation from equilibrium have been calculated for single-domain particles of antiferromagnetic material having either type of weak ferromagnetic moment. Of the four modes found, two have extremely high critical fields since they involve rotation in opposition of the sublattice moments at the expense of exchange energy. The two reversal modes of interest are (initially) rotations of the M_i about axes parallel and perpendicular to the particle axis, principally at the expense of anisotropy energy. If the initial character of the motion is assumed to persist, the mode $\Omega_\perp$ would be a 180° rotation of $m \equiv M_1 + M_2$ and $l \equiv M_1 - M_2$ in the plane of the M_i and the particle axis. The mode $\Omega_\parallel$ would be a 180° rotation of l in the plane perpendicular to the particle axis while simultaneously m decreases to zero and then grows to equilibrium value in the opposite direction along the particle axis such that $l^2 + m^2 = \text{constant}$. The critical fields for these two modes are given by the zero frequency limits of the dynamic resonance equations as pointed out by Brown. In general, the smallest critical fields will be found for the $\Omega_\perp$ mode in Dzialoshinsky-Moriya type weak ferromagnets with small, but finite, basal plane anisotropy. The lowest $|H_c|$ calculated is 40 oe for αFe_2O_3.

24,176 STATIC MAGNETIZATION REVERSAL IN THIN FILMS OF Co-Ni-P by G. Bate, D.E. Speliotis and J.R. Morrison (IBM); J. Appl. Phys., Vol.35, pp. 972-973, Mar. 1964

The process of magnetization reversal was studied by using a sensitive Hall probe to measure and map the horizontal component of the flux above the surface of the film after increasing reverse fields have been applied. It was found that these films employ a unique mode of magnetization reversal. Initially, small regions of reversed magnetization are established throughout the film, and these regions grow together to form elongated switched areas whose long dimensions are always perpendicular to the direction of applied field. The reversal pattern is highly reproducible in a given sample for a given field direction and reverses when the field direction reverses. This switching behavior is dependent on the direction of the field with respect to the sample, the long direction of the reversed regions always being perpendicular to the applied field. The sign of the vertical component of the flux from the sample was compared above and below the sample to determine whether magnetization perpendicular to the film plane

xisted. No such regions were found with a Hall probe of sensitive area down > 25 x 25 μ.

4,177 EFFECT OF COLD ROLLING ON MAGNETIZATION REVERSAL OF IGH-PURITY NICKEL TAPES by A.A. Hirsch (Israel Inst. Tech., Haifa); . Appl. Phys., Vol. 35, pp. 909-910, Mar. 1964

ynamic magnetoresistance hysteresis loops have been used for investigation of he magnetization reversal in cold-rolled tapes of high-purity nickel. The tapes ere prepared by unidirectional rolling as well as by rolling with reversing tape nd for end between passes. The loops were cycled in the range ± 4500 oe with variety of frequencies f from 0.005 to 0.1 cps in the wide interval of temperatures from 297° to 4.2°K. When the magnetization field was transverse to the olling axis, the coercive force could be expressed by $H_c = A(\ln f - \ln f_0)T^{1/2}$, here A and f_0 are in general dependent on the reduction of the tape thickness, nd vary slightly with the temperature T. Such a relation may be related to a agnetization reversal occurring through a process of reorientation of spins, hich can be described as a temperature-activated domain-wall relaxation. he magnetoresistance loops of the samples made by unidirectional cold rolling ere asymmetric when they were performed by applying simultaneously two rossed magnetic fields, one ac and the other dc. A magnetic uniaxial anisoopy induced by this rolling seems to be responsible for the observed asymmey, a possible mechanism for this being the deformation of crystals by slips.

4,178 FLUX REVERSAL AT LOW TEMPERATURES by F.B. Humphrey (Califoia Inst. Tech.); J. Appl. Phys., Vol. 35, pp. 911-912, Mar. 1964

ast flux reversal in thin (2000 A) Permalloy films has been observed at 77° and °K and compared to room temperature. The inverse of the reversal time as a unction of drive field with initial angle as a parameter was plotted. The switchng coefficient S_w of the low-drive region increased threefold which is inconstent with a simple, eddy-current-damped domain wall motion model since he conductivity changed only 17 per cent over the same range. The switching oefficient for the intermediate-drive region is essentially constant to 77°K and hen increases as the temperature is reduced in a manner inconsistent with an ntrinsically damped nonuniform rotational mechanism. The thresholds in this egion doubled, as did the anisotropy field H_K between 296° and 4°K. The igh-drive region does not change with temperature consistent with a coherent otational model.

4,179 FLUX REVERSAL IN RARE-EARTH-SUBSTITUTED YTTRIUM IRON GARNETS by W. Palmer (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, p. 918, Mar. 1964

he switching properties of polycrystalline toroids of pure YIG and YIG conaining 1% Dy, 3% Dy, and 4% Sm have been measured over the temperature ange 4.2° to 300°K. In each of the rare-earth-substituted materials, the field equired to switch 50% of the flux in a given time shows a peak at a temperaure which is approximately 0.4 times the temperature at which a peak is oberved in the ferrimagnetic resonance linewidth. Measurements of the frequency dependence of the linewidth of rare-earth-substituted YIG have indicated hat the loss mechanisms in these materials are "slow" relaxation processes. For low relaxation processes the linewidth is given by the expression $\Delta H(T, \omega\tau) = (T)\omega\tau/1+\omega^2\tau^2$, where ω is the experimental frequency and τ is the relaxation ime. $H-H_0(T, V\pi\tau/d)$ should depend in a similar way on $V\pi\tau/d$. This requires hat $V\pi\tau/d$ be a double-valued function of $H-H_0$, the higher value of which s inaccessible. The increase of ωτ beyond unity contributed to the decrease of he linewidth at low temperature, but the decrease in the switching field at ow temperature cannot be explained in this way. If the switching time chosen or reference were sufficiently short that at low temperatures $V\pi\tau/d$ increases eyond unity, the required field would not be reduced but a discontinuous increase in switching speed, which is not observed, would occur at the field $H-H_0(T, V\pi\tau/d = 1)$. However, the behavior of the switching field is understandable if the explicit temperature dependence of $H-H_0(T, V\pi\tau/d)$ is such as to produce the observed decrease at low temperature.

24,180 GRAIN SIZE EFFECTS IN SILICON STEELS UPON THE AC CORE LOSS COMPONENTS by R.E. Lenhart (Crucible Steel); J. Appl. Phys., Vol. 35, pp. 861-862, Mar. 1964

For some time it has been recognized that the sum of the classical eddy-current core loss and the loss represented by the dc hysteresis loop does not equal the total core loss. This error has been referred to as the anomalous or unaccounted loss. In revent years attempts have been made to account for this anomalous loss by utilizing modern domain concepts. It has been postulated that at small ratios of domain size to sheet thickness the anomalous loss should go to zero. Likewise at large ratios of domain size to sheet thickness, the eddy-current loss could be several times that predicted by the classical equation. In an attempt to explore the effects of grain size upon core loss components, it was found that the anomalous loss was nearly independent of grain size at constant thickness. If it is assumed that the magnetic domain size increases with increasing grain size, these measurements refute the importance of the changing domain size in the modern domain eddy current theories. However, it was noted that the dc hysteresis loss portion of total core loss changes significantly with grain size.

24,181 ORIGIN OF BIAXIAL ANISOTROPY IN POLYCRYSTALLINE FILMS by R.J. Prosen, Y. Gondo and B.E. Gran (Honeywell Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 826-827, Mar. 1964

A fourfold symmetry of anisotropy is found in polycrystalline films evaporated on unidirectionally scratched glass substrates. The origin of the biaxial anisotropy is attributed to a shape effect resulting from fine structure of the scratches. In essence, the fine structure of films deposited on such substrates is an array of oriented rectangularly shaped areas as confirmed by electron microscopic observation. Such arrays are simulated by depositing polycrystalline films by several methods in a regular array of small, discrete squares. Torque curves of the films have a large $\sin 4\theta$ component with the easy directions along the diagonals of the squares. The biaxial anisotropy constant estimated from the torque curves has the maximum value at a low measuring field and does not extrapolate to zero at high fields. Orthogonal switching experiments at low fields, where the magnetization rotates by 90° instead of 180°, also confirm the biaxial anisotropy related to the square shape. Based on these results, a domain configuration in the small square film at low fields, that consists of a central closure domain with an outer unclosed region, is proposed.

24,182 INDUCED MAGNETIC ANISOTROPY AND ORDERING IN Ni-Fe SINGLE CRYSTALS by M. Takahashi, T. Sasakawa and H. Fujimori (Tohoku U.); J. Appl. Phys., Vol. 35, pp. 869-870, Mar. 1964

The temperature dependence of the induced magnetic anisotropy by magnetic annealing has been measured in Ni-Fe single crystals containing 91.0%, 74.6% (Ni_3Fe), 69.0%, and 65.6% nickel. The ratios of the coefficients of the induced anisotropy energy, k_2/k_1, were almost constant with annealing temperature and had the value of 8.7 for Ni_3Fe, 3.9 for 69.0% Ni and 2.3 for 65.0% Ni in disordered state while these values changed remarkably when specimens were annealed just below the order-disorder transition temperatures. This result cannot be explained by the atomic orientation theory based on the crystal structure even though higher approximation methods are used.

24,183 INHOMOGENEITY IN THE MAGNITUDE OF THE ANISOTROPY FIELD IN THIN NICKEL-IRON FILMS by H.N. Oredson and E.J. Torok (UNIVAC); J. Appl. Phys., Vol. 35, pp. 810-811, Mar. 1964

The inhomogeneity in the magnitude of the anisotropy field of vacuum-deposited nickel-iron films has been measured as a function of film composition, inhomogeneity in composition, substrate temperature, time interval of deposition, and diameter of the film. The part of the inhomogeneity in the magnitude of H_k due to the product of the magnetostriction and the nonisotropic strain is found to be twice the part of the inhomogeneity in the direction of H_k due to this cause, as predicted by Crowther. Part of the inhomogeneity in magnitude but not in direction of H_k is attributed to nonuniformity in substrate temperature, and part to magnetocrystalline anisotropy.

24,184 INDUCED ANISOTROPY IN IRON-DEFICIENT Ni-Co FERRITES AT LOW TEMPERATURES by M. Mizushima and M. Hoshino (Sony Corp.); J. Phys. Soc. Japan, Vol. 19, pp. 281-287, Mar. 1964

The anisotropy Ku at -183°C in iron-deficient Ni-Co ferrites cooled down from room temperature in magnetic field is observed. It increases rapidly with decreasing contents of Fe_2O_3 and seems to attain a saturation value at a certain value of Fe_2O_3 contents. It also increases approximately in proportion to Co concentration. The activation energy for this process is about 0.25 to 0.4 ev. This anisotropy has been explained in terms of the preferential occupation of Co^{3+} ions in the four kinds of 16d sites arising from electron migration between Co^{2+} and Co^{3+} ions. The anisotropy Ku is not observed in iron deficient Mg-, Mn-, and Cu-ferrites containing a small amount of Co.

24,185 VARIATION WITH TEMPERATURE OF THE MAGNETOCRYSTALLINE ANISOTROPY OF SEVERAL NICKEL IRON FERRITES by F.W. Chapman, R.E. Michel and R. Poplawsky (Genl. Motors Res. Labs.); J. Appl. Phys., Vol. 35, pp. 1063-1064, Mar. 1964

An investigation of the magnetocrystalline anisotropy K_1 by microwave resonance measurements is reported for a series of nickel iron ferrite crystals in the temperature range of 4.2° to 300°K. Values of K_1/M_s, where M_s is the saturation magnetization, calculated from previous torque measurements of K_1 on similar materials agree with the present measurements of K_1/M_s over a temperature range from 300°K to some lower temperature that is dependent on the composition. At this temperature, which decreases with increasing Fe^{2+} content, the microwave values of K_1/M_s decrease sharply, while those derived from torque measurements continue to increase with decreasing temperature. The linewidth ΔH is anisotropic and temperature dependent with ΔH in the [111] direction exhibiting a maximum as a function of temperature. The value of g-effective increases as the temperature is lowered. There is qualitative, although not quantitative agreement between these data and theoretical results due to Clogston. Large magnetic annealing effects occur for each sample below a certain temperature. This temperature also depends upon the Fe^{2+} content.

24,186 INDUCED ANISOTROPY IN YIG WITH Si AND Mn ADDITIONS by E.M. Gyorgy and F.J. Schnettler (Bell Labs.); J. Appl. Phys., Vol. 35, pp.

1067-1068, Mar. 1964

The induced anisotropy in YIG (yttrium iron garnet) with Si and Mn additions has been studied. At 300°K the induced anisotropy increases with increasing Mn concentration and is zero for the samples containing Si. At 195°K an induced anisotropy could not be detected in any of the samples. At 77°K the YIG sample as well as the samples containing Si had an induced anisotropy whose magnitude increased with increasing Si. These results are consistent with the model attributing the induced anisotropy to localized Jahn-Teller distortions. They do not, however, invalidate other explanations.

24,187 FIELD DEPENDENCE OF ANISOTROPY IN YTTERBIUM-DOPED YTTRIUM IRON GARNET by R.F. Pearson and K. Tweedale (Mullard Res. Labs.); J. Appl. Phys., Vol. 35, pp. 1061-1062, Mar. 1964

Torque curves have been measured on two single crystals of Yb-doped yttrium iron garnet (containing 5% or 10% Yb) at temperatures from 77° to 4.2°K. At 20°K the maximum peak height of the (110) torque curve for these crystals was reduced by 12% as the applied field increased from 5000 to 15,000 oe; the change in peak height is approximately given by the relation $\Delta L = 0.32\,\Delta H$, where ΔL is measured in ergs/cm^3 and H is in oersteds. This field dependence was more pronounced at 14°K but had disappeared at 4.2° and 77°K. The energy of the Yb ground-state doublet (assumed to be well separated from other states) is represented by a spin Hamiltonian of the form

$$\mathcal{H} = H_e \cdot G \cdot S + H_a \cdot g \cdot S,$$

where $H_e \cdot G$ is the exchange splitting, and H_a is the applied field and g is the usual paramagnetic tensor for this doublet level with $S = \frac{1}{2}$. The temperature variation of the free energy of the system derived from this Hamiltonian was used to compute (110) torque curves as a function of temperature, applied field and concentration of ytterbium. These theoretical curves were then compared with the experimental results, and gave good agreement for the predicted value of $\Delta L/\Delta H$ at the maximum torque peaks, though as had been previously noted the absolute values of the torque are lower than those found experimentally.

24,188 ANISOTROPY IN THE BASAL PLANE OF HEMATITE SINGLE CRYSTALS by P.J. Flanders and W.J. Schuele (Franklin Inst. Lab.); Phil. Mag., Vol. 9, pp. 485-490, Mar. 1964

A sixfold torque curve, indicative of a triaxial anisotropy, has been found in the basal plane of some natural hematite single crystals. The anisotropy constant K obtained from the torque varied from 7 ergs/cm^3 to 188 ergs/cm^3 over the range of samples. Associated magnetic measurements on these crystals included remanence as a function of angle, moment, coercive force, susceptibility and rotational hysteresis.

24,189 TORQUE AND ROTATIONAL HYSTERESIS IN FCC SINGLE-CRYSTAL COBALT FILMS by W.D. Doyle (Franklin Inst. Lab.); J. Appl. Phys., Vol. 35, pp. 929-930, Mar. 1964

The Stoner-Wohlfarth coherent rotation model is extended to the case of biaxial anisotropy. The rotational hysteresis W_r as a function of reduced field h is zero for all values of h except $0.25 \leq h \leq 1$, and the maximum value of $W_r/K = 2.38$ at $h = 0.25$. The rotational hysteresis integral W equals 1.54. Measurements on fcc single-crystal Co films ($-K = 4 - 6 \times 10^5$ ergs/cm^3) prepared by epitaxial evaporation onto the (100) face of single-crystal MgO slabs held at 400°C yield results in wide disagreement with the theory. While the expected angular symmetry of the torque is observed, the model does not correctly predict the magnitude of the torque nor the fields at which specific types of angular dependence will be observed. The rotational hysteresis begins in every case before the predicted onset and continues beyond the expected cutoff. The maximum value of W_r/K and W are found to vary from 1.0 to 1.6 and from 2.9 to 1.7, respectively. It is concluded that the magnetization reversal process in single-crystal Co films is not coherent and that, as in the case of polycrystalline films, noncoherent rotations or wall motions must be investigated. This situation in single-element, single-crystal films calls for a reappraisal of the importance of compositional inhomogeneities and local crystalline anisotropy in polycrystalline alloy films.

STRUCTURAL PROPERTIES

24,190 NEW HEXAGONAL FERRITE, ESTABLISHING A SECOND STRUCTURAL SERIES by J.A. Kohn and D.W. Eckart (USAERDL); J. Appl. Phys., Vol. 35, pp. 968-969, Mar. 1964

The hexagonal ferrites, of current interest because of their high-frequency properties, are being studied by single-crystal X-ray methods. A new rhombohedral member of the group, ideally $Ba_4Zn_2Fe_{52}O_{84}$, has been identified. The centrosymmetric space group is $R\bar{3}m$; referred to hexagonal axes, c = 153.85 A, a = 5.88 A, and there are 66 anion layers in the c-axis repeat period. The stacking sequence was established by (00·l) structure factor and one-dimensional electron density calculations. The new structure forms a series of mixed-layer compounds with three of the original phases. All of the hexagonal ferrites are thus characterized by two series, each of which features the c-axis interlayering of two discrete structural units. Stacking relations within and between the two series are discussed, along with implications for new structures and series.

24,191 DOMAIN STRUCTURE OF HCP AND FCC COBALT ABOVE ROOM TEMPERATURE by P.J. Grundy and R.S. Tebble (U. Sheffield); J. Appl. Phys., Vol. 35, pp. 923-924, Mar. 1964

Lorentz transmission electron microscopy has been used to observe the magnetic domain structures in thin cobalt foils above room temperature. The changes in domain pattern occurring with increase in temperature in a crystal of the hcp phase are related to magnetocrystalline anisotropy measurements, and to the rotation of the easy direction of magnetization from the [0001] c axis to a direction in the basal plane at about 275°C. The domain pattern, in a crystal of the fcc phase, at elevated temperatures, is also in agreement with anisotropy measurements. In a region of mixed phase there is rotation of the magnetization direction from a [111] direction to a [110] direction in the fcc areas, in disagreement with anisotropy measurements.

24,192 DOMAIN STRUCTURE OF NARROW THIN FILMS OF Ni-Fe by K. Kuwahara, T. Goto, A. Nishimura and Y. Ozaki (Hiroshima U.); J. Appl. Phys., Vol. 35, pp. 820-821, Mar. 1964

Narrow thin films of 80 Ni-20 Fe have been produced by evaporation onto a glass substrate with a mask having several slits. The films were 15 ~ 300 μ wide, 400 ~ 1500 A thick, and 4 ~ 80 oe in H_K perpendicular to their long direction. Bitter patterns on the films having H_K of several oe showed the closure domains as proposed by Kittel. The energy density of the 180° walls between the adjacent main domains was measured to be 0.8 erg/cm^2, by observing the spacing of the walls and the width of the films. The films having higher H_K did not exhibit closure domains but only 180° walls parallel to the easy axis, as was also proposed by Kittel. By bending the substrate mechanically, H_K was increased in the films having closure domains. The transition, from the structure of closure domains into that of no closure domains, was observed as expected.

24,193 QUANTUM THEORY OF DOMAIN-WALL MOTION by J.F. Janak (MIT); Phys. Rev., Vol. 234A, pp. A411-412, Apr. 20, 1964

In disordered systems, such as ferrite, the resonance linewidth and domain-wall damping due to "fluctuations" should agree to within a factor of order unity. The motion is not describable by the Landau-Lifshitz equation. This communication is intended to demonstrate that a formulation for the quantum-mechanical study of domain-wall motion exists, and has the properties necessary to explain the losses which occur during such motion; it is not intended to lead to any quantitative results which can be directly compared with experiment. The specific heat contribution due to the domain wall is proportional to T above about 10^{-2}°K. It should be possible to observe such a specific heat contribution in YIG below 1°K.

24,194 WALL MOTION BY REVERSE NÉEL WALLS IN THIN FILMS by C.E. Patton, III and F.B. Humphrey (California Inst. Tech.); J. Appl. Phys., Vol. 35, pp. 921-922, Mar. 1964

Néel walls are presumed to exist as domain boundaries in thin films with thicknesses below 500 A. Low-drive switching with a superimposed transverse field H_t may take place by reverse wall motion ($H_t \cdot H_{wall} < 0$) or normal wall motion ($H_t \cdot M_{wall} > 0$). Wall velocities are determined by intrinsic damping rather than eddy current losses, for films in this thickness region. Reverse wall mobilities have been measured by interrupted pulse flux reversal experiments, in agreement with calculations based on the Landau-Lifshitz equation and uniaxial anisotropy. With $h = H_t/H_K = 0.1$, normal wall mobility is about 20 per cent greater than reverse wall mobility.

24,195 ORIGIN OF DOMAIN-WALL CREEPING IN MAGNETIC FILMS by A. Green, K.D. Leaver and M. Prutton (Intl. Computers and Tabulators); J. Appl. Phys., Vol. 35, pp. 812-813, Mar. 1964

On the assumption that domain-wall creeping in thin films is associated with changes in the magnetization distribution of a wall, four mechanisms are described that may account for the wall creeping. They are discussed in relation to the available experimental evidence. Further experiments, suggested to determine the validity of the mechanisms, concern in particular the frequency dependence of creep and the coercivity of pure Néel walls.

24,196 TEMPERATURE DEPENDENCE OF DOMAIN WALL CREEP IN THIN Ni-Fe MAGNETIC FILM by M.E. Sweet (IBM, Owego); J. Appl. Phys., Vol. 35, pp. 814-815, Mar. 1964

The temperature dependence of the creep of magnetic domain walls in a uniaxial thin Ni-Fe magnetic film and its relationship to the temperature dependence of the anisotropy field (H_k), the coercive force (H_c), and the critical fields required to initiate domain wall motion have been studied. The temperature dependence of creep velocity is measured with a peak transverse ac mag-

etic field ($H_{T\,ac}$) applied in the hard direction of magnetization and a dc ngitudinal field (H_L) applied in the easy direction. Measurements were made n a vacuum deposited thin film, 1613 A thick with a composition of 82.2 per ent Ni and 17.8 per cent Fe, using the longitudinal Kerr magneto-optic ef- ct. The thin film temperature was maintained to within ± 0.8°C over the nge 8.9 to 81.7°C. Experimental results show that domain wall creep veloc- y and the magnetic properties of the film are temperature dependent and that e temperature dependence of the former is related by a transformation to the mperature dependence of the latter. Curves of creep velocity, H_c, H_k as unctions of temperature are given, and experimental and constructed curves of onstant creep velocity were plotted at several temperature values to show that correlation exists between the experimentally measured values and the calcu- ited values.

4,197 AN INVESTIGATION INTO THE USE OF INTENSITY OBSERVATIONS N THE ELECTRON MICROSCOPE FOR DETERMINING MAGNETIC DOMAIN ALL WIDTHS IN THIN FOILS by D.H. Warrington (Sheffield U.); Phil. Mag., ol. 9, pp. 261-275, Feb. 1964

he contrast to be expected from several magnetic domain walls of interest is iscussed in the limiting case of a parallel incoherent electron beam. The ef- ct of a finite beam divergence and coherency content of the illuminating eam are then considered and it is shown that before a complete calculation the coherency effect is undertaken, the best measurement of domain wall idths is to be obtained from divergent walls. Corrections for beam divergence ffects are presented in detail.

4,198 LORENTZ MICROSCOPY OF MAGNETIC DOMAINS OF SINGLE- RYSTAL FILMS by H. Sato, R.W. Astrue and S.S. Shinozaki (Ford Motor); Appl. Phys., Vol. 35, pp. 822-823, Mar. 1964

omain patterns of epitaxially grown iron single-crystal films are investigated y the Lorentz microscopy technique. The width of 180° walls appear much wi- er than that of 90° walls. Double 90° walls and the fine structure of 180° alls, such as Bloch lines, etc., are observed.

ffects of Defects on Domain Walls in Ferromagnets - See 24,151

FERRO- AND FERRIMAGNETIC RESONANCE

4,199 QUANTUM STATISTICAL THEORY OF FERROMAGNETIC RESO- NANCE AT HIGH TEMPERATURES by O.A. Ol'khov (Acad. Sci. USSR); Soviet hys.-Solid State, Vol. 5, pp. 1784-1788, Mar. 1964

quations describing the behavior of the magnetization of a system with a strong xchange interaction in the high temperature region are derived using the den- ity matrix technique. In accordance with experimental data, the solution of he equations shows that the form of the absorption line for strong magnetizing elds is Lorentzian, while in the absence of the magnetizing field the expres- ion for the line transforms into the Debye formula for absorption in the zero ield.

4,200 ORIENTATION DEPENDENCE OF RESONANCE SECOND HARMON- IC, AND SPIN WAVES IN ANISOTROPIC FERROMAGNETIC CRYSTALS by G.F. Herrmann (Lockheed Res. Lab.); J. Phys. Chem. Solids, Vol. 25, pp. 47-351, Mar. 1964

General expressions are presented for the fundamental resonance frequency, he longitudinal second harmonic, and the spin wave spectrum in anisotropic erromagnetic crystals, for arbitrary orientation of the magnetization vector. he expressions are given in terms of the cartesian components (directional co- ines) of the magnetization, and therefore possess an inherently symmetric form f considerably generality.

24,201 MODULATION EFFECTS IN MAGNETIC RESONANCE: WIDTHS AND AMPLITUDES FOR LORENTZIAN AND GAUSSIAN LINES by G.W. mith (Genl. Motors Res. Labs.); J. Appl. Phys., Vol. 35, pp. 1217-1221, Apr. 1964

The effect of modulation amplitude on magnetic resonance linewidths δH (be- ween slope extrema) and derivative signal intensity is examined. Experimen- al results are compared with theory for Lorentzian and Gaussian lines. Modu- ation amplitudes, h_m, of 0.156H[or $2h_m$ (peak to peak) = 0.306H] produce bout 2 per cent error in linewidths for Lorentzian signals and less than 1 per ent error for Gaussian signals. Effects of modulation on linewidth and signal mplitude are presented in graphic and tabular form.

24,202 FERROMAGNETIC RESONANCE OF SINGLE-CRYSTAL GADOLINI- UM by T.W. Moore and D.S. Rodbell (GE Res. Lab.); J. Appl. Phys., Vol. 35, p. 906, Mar. 1964

The ferromagnetic resonance behavior of a single crystal at frequencies of 21 and 35 Gc/sec and at temperatures from above the Curie point (20°C) to 4.2°K has been measured. The resonance absorptions are well defined at both frequencies and at all temperatures for most crystal orientations. The minimum linewidth observed is about 400 oe but the line shape and width degrade when the applied field departs from the easy axis, particularly at the lower frequency and at low temperatures. Strong, well-defined domain wall resonances are also frequently observed. The deduced magnetocrystalline anisotropy energy is accurately described by the standard uniaxial expansion $E_A = K_1 \sin^2\theta + K_2 \sin^4\theta + \cdots$, about the hexagonal axis. The anisotropy constants derived from the resonance data agree reasonably well with those measured by Graham using static torque methods. The spectroscopic splitting factor, g, is 2.00±0.02 below 0°C, changing smoothly to 1.94±0.02 at 28°C in the paramagnetic region.

24,203 FERROMAGNETIC RESONANCE LINEWIDTH AND INTERNAL BIAS- ING FIELD IN Ni-Fe FILMS AS A FUNCTION OF DISPERSION IN THE ANI- SOTROPY FIELD MAGNITUDE by R.H. Nelson (UNIVAC); J. Appl. Phys., pp. 808-809, Mar. 1964

Ferromagnetic resonance techniques have been used to measure the magnetic properties of Ni-Fe films in the 50-1500 Mc/sec range. Resonance was observed in the plane of films 8 mm in diameter and 600-2600 A thick. The zero frequency linewidths found were about 2.8 times the values calculated theoretically from values of anisotropy field magnitude dispersion obtained independently. Plots of the resonance frequency squared as a function of resonance field showed a shift, or internal bias H_i, toward positive field values as others have observed. There was little or no shift for films with Δ_{90} less than 0.2, but for larger dispersion, the shift increased approximately linearly with Δ_{90}. A very good linear correlation was found between H_i and α_0, the high-frequency damping parameter. It is suggested that the internal biasing field may be associated with the magnetization rippling that Fuller and Hale and Feldtkeller have observed in electron micrographs. Also, it may be possible that the larger-than-expected values of $(\Delta H)_0$, and the wide variation in α_0 values (0.006-0.03) reported here are caused by the energy loss, which Feldtkeller has termed "ripple hysteresis," associated with the movement of the small-angle walls, which result from the magnetization rippling.

24,204 MICROWAVE RESONANCE AND RELAXATION OF MANGANESE IRON FERRITES by B.H. Clarke and R.W. Teale (Mullard Res. Labs.); J. Appl. Phys., Vol. 35, pp. 892-893, Mar. 1964

Microwave resonance measurements are reported at 16.85 Gc/sec in the temperature range 1.5° to 300°K for single crystals of composition $Mn_xFe_{3-x}O_4$ with x = 1.318, 1.007, and 0.990. For x = 1.318, the linewidth and the g factor, if this is calculated in the usual way, both pass through maxima as a function of temperature. These effects are compared to the predictions of a slow relaxation model, and indicate a splitting of a low-lying pair of energy levels of about 7.5 cm^{-1}, and relaxation times across these levels of about 10^{-11} sec. The specimens close to manganese ferrite also show these relaxation effects but on a much reduced scale. They give splittings and relaxation times similar to those above. Sharp peaks in the linewidth as a function of orientation were found at [110] directions at 4.2°K and below, and were similarly dependent on composition. It is suggested that the slow relaxation is associated with manganese ions of some sort.

24,205 FERROMAGNETIC RESONANCE IN SINGLE-CRYSTAL EUROPOUS OXIDE by J.F. Dillon, Jr. (Bell Labs.) and C.E. Olsen (Los Alamos); Bull. Am. Phys. Soc., Vol. 9, p. 260(A), Mar. 1964

Ferromagnetic and paramagnetic resonance were observed at 23.5 and 25.5 Gc/sec over a temperature range 1.5°-300°K. The best sphere was a rather large 0.63 mm in diameter. The linewidth increased from about 800 oe at low temperatures to about 1400 oe at room temperature, with no particular anomaly near the Curie temperature. Apparently, these wide lines in the ferromagnetic state can be attributed to impurity scattering. Because of the large moment and low exchange energy, scattering by voids and nonmagnetic inclusions would give linewidths perhaps 10^3 times larger than in a geometrically equivalent crystal of, say, yttrium iron garnet. The anisotropy at liquid-helium temperatures is given approximately by $K_1/M = -190$ oe. Between 160° and 300°K, the spectroscopic splitting factor g = 2.00±0.01.

24,206 IMPROVEMENT OF THE FERROMAGNETIC RESONANCE LINEWIDTH OF SINGLE-CRYSTAL ZnY ($Ba_2Zn_2Fe_{12}O_{22}$) BY A NEW GROWTH TECHNIQUE by A. Tauber, S. Dixon, Jr., and R.O. Savage, Jr. (USAERDL); J. Appl. Phys., Vol. 35, pp. 1008-1009, Mar. 1964

By using a new growth technique, ferromagnetic resonance linewidths as low as 8.0 oe can be obtained in ZnY single crystals at room temperature and 0.9 kMc. These crystals were grown in platinum crucibles from $BaO-B_2O_3$ melts. The melts were found to be less volatile and less viscous than $NaFeO_2$ melts. Annealing reduced the linewidth. The best conditions consisted of annealing raw crystals at 750°C in 1 atm of oxygen for 24 hrs. This treatment reduced the ferrous ion concentration to below the limit of detection, 0.01 per cent, and is considered the major factor in linewidth reduction. These samples were then ground into

spheres and polished with successively finer grit abrasives. An exponential decrease in the linewidth was observed as a function of grit size. Linewidth measurements were made using the standard cavity perturbation technique. The diameters of the samples ranged from 0.018 to 0.030 in. (450 to 750 μ). The orientation of spheres in the cavity was such that the microwave magnetic field and the applied field were perpendicular to each other and in the plane of easy magnetization of the material.

24,207 MAGNETIC RESONANCES AND SUSCEPTIBILITY IN ORTHOFERRITES by G.F. Herrmann (Lockheed Res. Labs.); Phys. Res., Vol. 133A, pp. A1334-1344, Mar. 2, 1964

Magnetic resonances and susceptibilities are calculated for various allowed magnetic structures in orthoferrites and similar magnetic perovskites. The calculation is based on a general form for the free energy which includes canting contributions from both single-ion anisotropy and antisymmetric exchange, and which assumes four distinct interacting magnetic sublattices. The results are compared with those obtained from a simplified 2-sublattice model, and the effect of hidden canting on overt behavior is evaluated. When antisymmetric exchange is the predominant canting mechanism, a 2-sublattice model presents a correct formal (but not necessarily physical) picture for the antiferromagnetic resonance modes and for low-frequency magnetic behavior, provided that exchange effects associated with hidden canting are properly incorporated within an effective anisotropy energy. This effective anisotropy will, in general, not have the physical properties, e.g., temperature dependence, typical of single-ion anisotropy. A 4-sublattice model is required for the analysis of the high-frequency exchange modes. It is found that these modes are coupled by the spin canting mechanism to the antiferromagnetic modes and as a result become optically active. In general, one finds that, of the many interaction coefficients possible in a 4-sublattice system, only relatively few can be determined by direct macroscopic measurement.

24,208 CERTAIN PECULIARITIES OF FERROMAGNETIC RESONANCE IN YTTRIUM GARNET HAVING RETAINED DOMAIN STRUCTURE by A.A. Manuilova; Soviet Phys.-Solid State, Vol. 5, pp. 2082-2086, Apr. 1964

Results of an investigation of ferromagnetic resonance in unsaturated yttrium garnet are reported. It is shown that the width of the additional absorption peak, due to the existence of the domain structure in the sample, decreases as the field in which this peak is observed approaches saturating intensity. Domain resonance occurs at various orientations of the dc magnetic field relative to the crystallographic axes. Saturation of domain resonance follows the same rules as saturation of the ordinary ferromagnetic resonance.

24,209 FERRIMAGNETIC RESONANCE OF RARE-EARTH-DOPED IRON GARNETS by J.H. Van Vleck (Harvard U.); J. Appl. Phys., Vol. 35, pp. 882-888, Mar. 1964

After a brief introductory sketch of the analogs in paramagnetic relaxation, the longitudinal and transverse (so-called "slow" and "fast" relaxing) mechanisms of line broadening as well as shifting by rare-earth impurities are described and compared, particularly for Kramers doublets. The longitudinal process is operative only if the rare-earth ions are anisotropically coupled to the iron magnetization, either because of the crystalline field or anisotropy in the exchange coupling tensor itself. Unless the anisotropy is small, the longitudinal process predominates when the splitting of the RE energy levels by the crystalline and exchange fields is large compared to the ferrimagnetic resonance frequency and to the relaxation frequency, as is usually the case at temperatures well below the Curie point. The longitudinal mechanism describes quite well the behavior of Yb in yttrium iron garnet except for one peculiar as yet unexplained peak in the linewidth at one angle at low temperatures. The line broadening with Eu comes from the excited state $J = 1$, and its variation with temperature and frequency is explicable with the longitudinal model. The "giant anisotropy frequency shifts" with Tb are presumably caused by abnormally small rare-earth energy intervals for certain angles. The $k = 0$ mode is mixed with other k modes by the rare-earth impurities. This effect is not ordinarily a major cause of line broadening, but may be for Tb at low temperatures.

24,210 A GREEN FUNCTION THEORY OF FERROMAGNETIC RELAXATION by M. Tanaka (Kyoto U.); Prog. of Theoret. Phys., Vol. 31, pp. 177-196, Feb. 1964

Ferromagnetic relaxation due to the dipolar interaction is investigated in terms of the two-time Green function. A general expression for the dipolar broadening is obtained which is applicable to the entire range of temperatures. The decay constant of the uniform mode is calculated and discussed in terms of its dependence on temperature and shape. A qualitative discussion of the damping constant near the critical point is given.

24,211 THE PROBLEM OF RESONANCE CURVE BROADENING NEAR THE CURIE POINT by H.C. Meng and L.A. Davydov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1919-1922, Mar. 1964

The broadening of the resonance curve near the Curie point θ is analyzed. It is shown that the linewidth due to magnetization fluctuations is proportional to $(\theta-T)^{1/2}$ under the condition $H \ll AM_\xi$ (molecular field). At the Curie po the linewidth has a finite value and is inversely proportional to the cubic roo of the field. Experimental data obtained from measurements of the linewidth yttrium garnet essentially confirm the $(\theta-T)^{-1/2}$ dependence.

24,212 FERROMAGNETIC RESONANCE RELAXATION, WIDE SPIN-WAVE COVERAGE BY ELLIPSOIDS by A.S. Risley and H.E. Bussey (Natl. Bu. Stan J. Appl. Phys., Vol. 35, pp. 896,897, Mar. 1964

The role of degenerate spin-wave coupling in ferromagnetic resonance (FMR) losses has been studied as a function of sample shape. Measurements of linewidth ΔH and peak absorption intensity s'' both show that FMR loss above th 90°, $k \to 0$ limit of the spin-wave spectrum is much less than within the spec trum. An investigation of unsymmetrically magnetized spheroids, i.e., with the external field H_0 not along the symmetry axis revealed that there are regions of the spin-wave spectrum which can be reached by more than one samp shape and that in these regions of overlap the different shapes yield different values of ΔH and s''. A similar result can be calculated from the usual equation of motion using either Landau-Lifshitz or Bloch-Bloembergen damping. (The asymmetric case has not yet been treated by the spin-wave model.) Despite the strong variation of ΔH and s'', the gyromagnetic ratio changed less than 1 per cent under all variations of shape and orientation. The variable shape technique gives greater coverage of the spectrum than previous variabl frequency work. Another advantage is that the unknown effects of changing frequency on other possible loss mechanisms are avoided.

24,213 LINEWIDTHS IN FERROMAGNETIC THIN FILMS by P.E. Wigen and M.R. Shanabarger (Lockheed Res. Labs.); J. Appl. Phys., Vol. 35, p. 804, Mar. 1964

An inhomogeneity in the magnetization of thin ferromagnetic films provides a mechanism for two-magnon scattering that contributes to the spin-wave resonance linewidth of thin ferromagnetic metal films. A normal (perpendicular) variation in the internal field has previously been assumed to explain the spin wave resonance properties of thin films. A variation of the magnetization in the plane of the film produces an inhomogeneously broadened linewidth. Since the inhomogeneity is much smaller than the average magnetization of the material, dipole forces decrease the inhomogeneous broadening of the resonance line. Experimental results are in good agreement with the theory when eddy current losses are included and account for an inhomogeneity in the plane of the film that is of the same order of magnitude as the normal inhomogeneity. As the film normal is rotated with respect to the magnetic field direction, the cri ical angle is approached at which the resonance conditions are the same throug out the film and the spins precess at a common frequency. At this angle the planar inhomogeneity is not effective in broadening the excited mode. This effect is indicated in the data by a minimum in the frequency linewidth at this angle. This calculation is consistent with data obtained from Permalloy, coba and nickel films at 10 and 15 Gc/sec.

24,214 FERROMAGNETIC RESONANCE IN SINGLE-CRYSTAL YTTRIUM IRON GARNET WITH RETAINED MAGNETIC STRUCTURE by B.M. Lebed' an L.Ya. Mukha; Soviet Phys.-Solid State, Vol. 5, pp. 2169-2171, Apr. 1964

Measurement of the effect of the domain structure on the conditions of ferromagnetic resonance in a single crystal of yttrium-iron garnet at frequencies of 1496 and 1010 Mc is reported. It is shown that when a constant magnetic field is oriented along the [110] and [100] directions and an alternating field is perpendicular to the constant field, two branches of resonance fields are observed due to the resonance absorption. No resonance is observed in the case of a parallel alternating field. The ferromagnetic resonance linewidth determined by the existence of the domain structure increases with increasing temperature.

24,215 DIPOLE-NARROWED INHOMOGENEOUSLY BROADENED LINES IN FERROMAGNETIC THIN FILMS by P.E. Wigen (Lockheed Res. Labs.); Phys. Rev., Vol. 133A, pp. A1557-1562, Mar. 16, 1964

An inhomogeneity in the magnetization of thin ferromagnetic films is shown to provide a mechanism for two-magnon scattering which contributes to the spin-wave resonance linewidth of thin ferromagnetic metal films. A normal (perpendicular) variation in the internal field has previously been assumed to explain the spinwave-resonance properties of thin films. In this work a planar variation in the magnetization is assumed which produces an inhomogeneously broadened linewidth. Since the inhomogeneity is much smaller than the average magnetization of the material, dipole forces will decrease the inhomogeneous broadening of the resonance line. Experimental results are in good agreement with the theory when eddy current losses are included and the inhomogeneity in the plane of the film is of the same order of magnitude as the normal inhomogeneity. As the film normal is rotated with respect to the magnetic field direction, the critical angle is approached at which the resonance conditions are the same throug out the film and the spins precess at a common frequency. At this angle the planar inhomogeneity will not be effective in broadening the excited mode. This effect is indicated in the data by a minimum in the frequency linewidth at this angle.

216 INTRINSIC FERROMAGNETIC RESONANCE LINEWIDTH IN METAL NGLE CRYSTALS by Z. Frait (U. North Carolina) and B. Heinrich (Czech. ad. Sci.); J. Appl. Phys., Vol. 35, pp. 904-905, Mar. 1964

results of the measurements of the ferromagnetic resonance (FMR) linewidth iron, fcc cobalt, nickel, silicon iron, and Permalloy single crystals at room perature at 9 2 and 3.6 Gc/sec are given. In these cases (except nickel) linewidth can be fully explained by the exchange broadening due to skin ect and surface spin pinning. The assumed values of the surface anisotropy not inconsistent with the values determined from spin-wave resonance of films. The hypothesis, that the intrinsic FMR linewidth of bulk metals (i.e. linewidth measured in a both statically and dynamically homogeneously gnetized material) should be no more than several oe (at least in some single stals) is supported by the frequency dependence of FMR linewidth.

217 RESONANCE LINE SHAPES OF WEAK FERROMAGNETS OF THE Fe_2O_3 AND NiF_2 TYPE by H.J. Fink (Bell Labs.); Phys. Rev., Vol. 133A, A1322-1326, Mar. 2, 1964

ed on a two sublattice model the resonance line shapes of the low- and high- quency branch of weak ferromagnets of the α-Fe_2O_3 and NiF_2 type were cal- ated by solving the equations of motion with a damping term of the Landau- l-Lifshitz type. When the RF driving field is applied perpendicular to the romagnetic component and in the easy plane of the α-Fe_2O_3 type crystal, an ancement factor appears in the susceptibility. The frequency linewidth is portional to the exchange frequency and approximately independent of an lied field. The linewidths are compared with experiments and good agree- nt is found for $MnCO_3$. For $MnCO_3$ the damping of the high-frequency nch is by a factor of about 2.6 more effective than that of the low-frequen- branch.

218 SLOW AND FAST RELAXATION IN MAGNETIC RESONANCE IN RRIMAGNETIC $MnFe_2O_4$ by A.J. Heeger, T.G. Blocker III, and S.K. osh (U. Pennsylvania); Phys. Rev., Vol. 134A, pp. A399-406, Apr. 20, 1964

e Mn^{55} nuclear spin-lattice relaxation time, and the ferromagnetic-resonance ewidth in $MnFe_2O_4$ have been measured as a function of the temperature. important features of the data are a peak in $1/T_1$ at 3°K; and two peaks in ferromagnetic-resonance linewidth at 20° and 210°K, respectively. The -temperature phenomena are described in terms of a slow relaxation theory ed on the low-lying orbital levels of the Fe^{2+} impurities present; the peak $1/T_1$ occurring where $\omega_N\tau \sim 1$ and the peak in ΔH occurring when $\omega_0\tau \sim 1$ ere ω_N and ω_0 are the nuclear and ferromagnetic resonance frequencies, and s the relaxation time of the Fe^{2+} impurities. The high-temperature linewidth he result of a direct transition (via the spin-orbit interaction) between these els with annihilation of a k = 0 magnon, and becomes appreciable when ~ 1 where $\hbar\omega_1$ is the separation between the low-lying orbital levels. Anal- s of the low- and high-temperature data yield consistent values for the level aration, $\hbar\omega_1 \sim 10$°K, and for the temperature dependence of τ. At low tem- atures $1/\tau$ increases linearly with temperature suggesting a direct phonon or gnon relaxation process. Above 150°K, τ is limited by the lifetime of the sifree electron on a given Fe ion.

219 NUCLEAR AND FERROMAGNETIC RELAXATION IN $MnFe_3O_4$ by A. Heeger, T.G. Blocker III, and S.K. Ghosh (U. Pennsylvania); J. Appl. ys., Vol. 35, pp. 840-841, Mar. 1964

e Mn^{55} nuclear spin-lattice relaxation time, and the ferromagnetic resonance ewidth have been studied in the same single crystal of ferrimagnetic Fe_2O_4 as a function of the temperature. The low-temperature linewidth is curately described in terms of a "slow" relaxation theory based on the low- ng levels of the Fe^{2+} impurities present. The NMR T_1 results indicate that dominant nuclear relaxation mechanism arises from the complex frequency lling, brought about by "slow" relaxation in the ferromagnetic spin system.

220 NICKEL FERRITE CRYSTALS WITH A NARROW FERROMAGNETIC SONANCE LINE by S.S. Gendelev, B.L. Lopovok and B.E. Rubinshtein; viet Phys.-Solid State, Vol. 5, pp. 2223-2224(L), Apr. 1964

investigation of single-crystal nickel ferrite samples with a minimum line- dth of 9.5 oe at 9100 Mc and room temperature is reported. The temperature pendence of the linewidth measured in the (110) plane along the three prin- pal crystallographic directions is shown. The smallest value of the linewidth negative temperatures is observed in the [111] direction. The gradual in- ease in the linewidth with decreasing temperature indicates that the ferrite ntains only a small amount of impurities. The first and second constants of ystallographic anisotropy and the g factor were calculated at angles 0°, 30° d 54°44′ at various temperatures. Within the limits of measurement error the factor is nearly temperature independent.

rromagnetic Resonance in MnBi Films - See 24,452

221 DETERMINATION OF THE RESONANCE LINEWIDTH OF SPIN AVES by S.S. Starobinets (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1978-1979(L), Mar. 1964

A method for determining the linewidth of spin waves is proposed based on the assumption that the amplitude of the uniform precession increases beyond the unstability threshold. The method was used to calculate the linewidth for pure yttrium garnet, and the linewidth was found to be 1.0 oe. For yttrium garnet with a 0.05 per cent of dysprosium the value of the linewidth obtained is 1.95 oe.

24,222 SPIN-WAVE RESONANCE IN MAGNETIC FILMS ON THE BASIS OF THE SURFACE-SPIN-PINNING MODEL AND THE VOLUME INHOMOGENEITY MODEL by C.F. Kooi, P.E. Wigen, M.R. Shanabarger and J.V. Kerrigan (Lockheed Res. Labs.); J. Appl. Phys., Vol. 35, pp. 791-797, Mar. 1964

Two models of spin-wave resonance in magnetic films are briefly reviewed. These are the surface-spin-pinning model and the volume inhomogeneity model. The intensities and frequencies of the resonance lines, the spin-wave-phonon interaction, the critical angle, and several other experiments are then discussed in relation to these two models. It is concluded that the evidence tends to favor the volume inhomogeneity model with surface spin pinning being very weak or absent. A consequence of this conclusion is that it is very difficult to determine exchange parameters by means of spin-wave resonance in films.

24,223 EXPERIMENTAL STUDIES OF SPINWAVES EXCITED BY PARALLEL PUMPING by W.E. Courtney (Queen's U., Belfast) and P.J.B. Clarricoates (U. Leeds); J. Electronics and Control, Vol. 16, pp. 1-20, Jan. 1964

The excitation of spinwaves by a microwave magnetic field in the parallel-pump configuration is described. A swept magnetic field technique for detecting the absorption of microwave energy is employed. Values for the acoustic Q-factor, the magnetoelastic coupling coefficient and exchange constant are obtained for single-crystal yttrium-iron garnet. Verification of Morgenthaler's theory of spinwave-phonon interaction is provided. Experiments employing superimposed RF modulation of the magnetic field are in general agreement with Suhl's theory. Observations of relaxation oscillations have been made which differ from those previously reported.

24,224 SPIN-WAVE ANISOTROPY EFFECTS IN PARALLEL PUMPING IN YIG by J.C. Sethares, M.H. Seavey, Jr., T.G. Purnhagen and M.R. Stiglitz (AF Cambridge Res. Labs.); J. Appl. Phys., Vol. 35, pp. 898-899, Mar. 1964

A second "corner" has been observed on the "butterfly curve" of the parallel pumping experiment on YIG (yttrium iron garnet) at x-band frequency. The extra corner occurs in all crystallographic directions in a (110) plane except the [100] and [111]. The separation between the two corners closely equals the anisotropy-produced azimuthal angle splitting of the top of the spin-wave band. This splitting occurs in cubic YIG in all directions except the [100] and [111]. The shape of the butterfly curve in the region between the corners is partially explained by the variation in spin-wave ellipticity with azimuthal angle. A variation in spin-wave linewidth for $k \to 0$ with azimuthal angle may be responsible for the remaining discrepancy.

24,225 NUCLEAR MAGNETIC RESONANCE IN FERRIMAGNETIC Mn_xSn by N. Sato, R. Hoshino (Hokkaido U.), and M. Asanuma (Matsushita Res. Inst.); J. Phys. Soc. Japan, Vol. 19, pp. 139-140(L), Jan. 1964

Two nuclear magnetic resonances have been observed in Mn_xSn at liquid nitrogen temperatures. One occurred at 324 Mc and the other at 322 Mc. No clear information was obtained about line shape because the signals were too weak to be detected with an autodyne oscillator. A plot of resonant frequency as a function of manganese content at dry ice temperatures is presented. It was also found that the internal field at the tin nucleus decreases linearly with increasing manganese content.

24,226 VARIATION OF DOMAIN STRUCTURE WITH SURFACE ORIENTATION FOR MAGNETOPLUMBITE by R. Carey and E.D. Isaac (Lanchester Coll. Tech.); Phys. Lett., Neth., Vol. 8, p. 239(L), Feb. 15, 1964

The conditions under which the magnetostatic energy of magnetoplumbite is reduced by the μ^* effect are discussed. The μ^* effect is the rotation of magnetization vectors away from the easy direction by demagnetizing fields. For materials with high anisotropy, the surface energy of a specimen with a Kittel slab domain structure is reduced by a factor $\lambda(\phi) = 2/1+(1+k^*)^{1/2}(1+k^*\sin^2\phi^{1/2}$, where $k^* = 2\pi I_s{}^2/k$, I_s is the saturation magnetization of the material, k is the magnetocrystalline anisotropy energy, and ϕ is the angle between the surface and the crystal basal plane. Examination of the domain structures at the surface of a magnetoplumbite single crystal over the orientation range $0 < \phi < 90°$ has indicated that in this material reductions in the magnetostatic energy as a result of the μ^* effect alone occur only for the values of ϕ between 73° and 90°.

24,227 MAGNETOACOUSTIC EFFECT IN MOLYBDENUM NEAR 1 Gc/s by C.K. Jones and J.A. Rayne (Westinghouse); Phys. Lett., Neth., Vol. 8, pp. 155-156(L), Feb. 1, 1964

Measurements of the magnetoacoustic effect at 928 Mc in molybdenum single crystals are reported. All measurements were made at 4.2°K for $\vec{q} \parallel [110]$, the magnetic field direction being rotated about the propagation vector in a (110) plane. For $\vec{q} \parallel [110]$ and $\vec{H} \sim [111]$, two different periods of oscillation were observed. The short period of oscillation is most prominent around this field orientation. The average extremal wave vector for the short period oscillation is $k_{ext} = 0.48 \times 10^8$ cm^{-1}, and the corresponding extremal area is approximately 0.8 A^{-2}. It is suggested that the oscillation arises from orbits around the belly of the electron at Γ. The long period oscillation is roughly isotropic in field direction, with an average extremal wave vector $k_{ext} = 0.26 \times 10^8$ cm^{-1} and an extremal area of 0.21 A^{-2}. The experimental data support the model for the Fermi surface of tungsten and molybdenum proposed by Lomer.

24,228 MAGNETOACOUSTIC RESONANCE IN LITHIUM FERRITE by R.L. Comstock and J.P. Remeika (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 1018-1019, Mar. 1964

The parametric coupling of magnetostatic and elastic modes (magnetoacoustic resonance) has been observed in a single-crystal lithium ferrite sphere. Observation of this effect was made possible by the development of highly ordered stoichiometric lithium ferrite which has the narrowest ferromagnetic resonance linewidth of the spinel ferrimagnets [ΔH (300°K) = 1.7 oe, ΔH (134°K) = 0.9 oe at 5.4 G/sec]. The Q of the oblate-prolate elastic mode for this sphere was found to be 175,000 at 300°K. An estimate of one of the two magnetoelastic coupling constants resulted in a value $B_1 = 65 \times 10^6$ erg cm^{-3}. This estimate was made by comparing the magnetoacoustic threshold for a sphere of this material with the threshold for a sphere of yttrium iron garnet (YIG), for which the coupling constants are known. A figure of merit for magnetoelastic materials is presented on the basis of which it appears that lithium ferrite may be superior to YIG in some transducer applications.

24,229 GIANT OSCILLATIONS IN THE TRANSVERSE MAGNETOACOUSTIC ATTENUATION OF BISMUTH by A.M. Toxen and S. Tansal (IBM Res. Ctr.); Bull. Am. Phys. Soc., Vol. 9, p. 264(A), Mar. 1964

Measurements of the transverse magnetoacoustic attenuation of bismuth at temperatures down to 1.4°K in magnetic fields up to 17 kg are reported. The results are for shear waves of frequency 8-40 Mc/sec propagated in the bisectrix direction with the magnetic field in the binary direction. As Gurevich, Skobov, and Firsov have predicted, large oscillations in the magnetoacoustic attenuation were observed, similar to, but considerably larger than the de Haas-van Alphen or Shubnikov-de Haas effects. Both the maxima and minima of the absorption coefficient are approximately periodic in the reciprocal of the magnetic field. For values of ql, i.e., the product of sound-wave vector and electronic mean free path, in the range 0.1 to 1, the magnitude of the oscillations of attenuation coefficient increases monotonically with ql.

24,230 PARAMETRIC EXCITATION OF ACOUSTIC WAVE INSTABILITIES IN FERROMAGNETS by R.E. Tokheim, D.K. Winslow and B.A. Auld (Stanford U.); J. Appl. Phys., Vol. 35, pp. 1010-1011, Mar. 1964

Experimental measurements of saturation effects in single-crystal Zn_2Y, with the easy plane lying in the plane of the disk, have been observed experimentally at 1.3 Gc/sec - below the bottom of the spin-wave manifold. Thresholds observed are comparable with theoretical predictions based upon the assumption of the magnetoelastic pumping effect as the dominant mechanism. In these experiments the order of the first resonant spin-wave instability permitted has been varied from the second to the fifth by adjusting the position of the spin-wave manifold relative to the pump frequency.

24,231 HELICON-PHONON INTERACTION IN METALS by J.J. Quinn (RCA Labs.) and S. Rodriguez (Purdue U.); Phys. Rev., Vol. 133A, pp. A1589-1594, Mar. 16, 1964

An analysis of the transverse modes of oscillation of an electron gas in the presence of a strong longitudinal magnetic field is presented. These modes have been called helicons. The form of the dispersion equation of helicons of arbitrary wave vector is exhibited. The interaction of helicons with transverse acoustic waves in metals is then described. This interaction is particularly strong when the frequencies and wavelengths of a helicon and a transverse phonon coincide. It is suggested that this effect permits the excitation of transverse phonons by electromagnetic means. The interaction of helicons and phonons in the long-wavelength limit is also discussed.

24,232 PROPAGATION OF HELICON WAVES IN METALS by C.C. Grimes (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 239(A), Mar. 1964

Propagation of helicon waves through slabs of uncompensated metals has been studied at frequencies up to 100 Mc/sec. Some effects that are clearly observed by this technique are the damping edge due to cyclotron damping, quantum oscillations, and interaction of helicon waves with transverse sound waves. A crude measurement of the radius of curvature of the Fermi surface is obtained from the cyclotron-damping effects. For Na and K, the radii of curvature of the Fermi surfaces are in qualitative agreement with the free-electron values. The quantum oscillations observed in K, Al, and Ni are periodic in 1/H and appear to have the same periods as the de Haas-van Alphen effect. Helicon waves couple to transverse sound waves when the phase velocities of the two waves are nearly equal. This coupling has been observed for helicon-wave propagation through single crystals of potassium.

24,233 PROPAGATION OF HELICON WAVES IN ANISOTROPIC SOLIDS J.J. Quinn (RCA); Bull. Am. Phys. Soc., Vol. 9, p. 265(A), Mar. 1964

A number of new results concerning the propagation of helicon waves in anisotropic materials is discussed. These results are derived by using a specific model in which the Fermi surface consists of 3 ellipsoids of revolution about the (0, directions and in which intervalley scattering is unimportant. For propagation in the (0,1,1) direction, it is found first that the selection rule $\Delta n = \pm 1$ for t absorption of transverse waves does not hold. In particular, electronic transitions, in which $\Delta n = 0$, give rise to helicon attenuation even at the lowest frequencies. The presence of this absorption may make it quite difficult to determine accurately the position of the absorption edge for the Doppler-shifted cyclotron resonance. Second, it is found that geometric resonances in the attenuation of helicon waves should exist; the origin of these resonances is the same as that of the parallel-field magnetoacoustic effect. Third, quantum oscillation in the attenuation will occur. The period of the quantum oscillation may be used to determine nonextremal cross-sectional areas of the Fermi surf

ANTIFERRO- AND ANTIFERRIMAGNETISM

Band theory of Antiferromagnetism - See 24,129 and 24,130

24,234 VARIATIONAL TREATMENT OF THE HEISENBERG ANTIFERROMAGNET by H. Falk (USAERDL); Phys. Rev., Vol. 133A, pp. A1382-1389, Mar. 2 1964

A form of the Peierls free-energy variational theorem is applied to the Heisenberg Hamiltonian for a three-dimensional system with nearest-neighbor antiferromagnetic interaction. For a large magnetic field ($h \equiv g\mu H/4SJz \approx 1$) a phase boundary separating a region of antiferromagnetic order from one of ferromagnetic order is found. At low temperatures ($\theta \equiv kT/2SJz \ll 1$) the phase boundary has the leading behavior: $h = 1 - a\theta^{3/2}$ with $2\xi\ (3/2)(3/2\pi)^{3/2}/S$ for a simple cubic antiferromagnetic lattice (e.g., $RbMnF_3$). At the phase boundary the magnetization is continuous; whereas a discontinuity in the susceptibility is suggested but not firmly established by this treatment. Low-temperature expressions are given for the magnetization, susceptibility, and specific heat above the boundary. Numerical calculations show that, for the approximation used, the phase boundary extends to a maximum θ at which the magnetization is nonzero. For the limiting case of $h = 0$ Keffer and Loudon's renormalized spectrum and magnetization for a ferromagnet and for an antiferromagnet from a single variational calculation are obtained. Attention is also given to a reduced Hamiltonian which, when treated by the variational method, exhibits the properties of an antiferromagnetic molecular field model previously proposed by Garrett for $S = \frac{1}{2}$.

24,235 LOW-TEMPERATURE PROPERTIES OF A HEISENBERG ANTIFERROMAGNET by A.B. Harris (Duke U.); J. Appl. Phys., Vol. 35, pp. 798-799 Mar. 1964

It is shown how the propagator formalism can be used to obtain the low-temperature expansion of the free energy of an isotropic Heisenberg antiferromagnet. The lowest-order terms in such an expansion can be calculated using the proper self-energy evaluated at zero temperature. The analytic properties of this quantity are investigated by expressing it in terms of time ordered diagrams. The low-temperature expansion of the free energy is shown to be of the form $AT^4+BT^4+CT^8$, where A, B, and C are given by Oguchi correctly to order $1/S$. For spin $\frac{1}{2}$ the term in $1/S^2$ gives a 2 per cent reduction in A for a body-centered lattice.

Antiferromagnetic:
Coupling in CdS - See 24,081
Exchange - See 24,091

24,236 LOW-TEMPERATURE BEHAVIOR OF A FACE-CENTERED CUBIC ANTI FERROMAGNET by A. Danielian (U. London King's Coll.); Phys. Rev., Vol. 133A, pp. A1344-1349, Mar. 2, 1964

A detailed description of the ground state of a face-centered cubic antiferromagnetic system with Ising interactions is followed by an investigation of the low-temperature thermodynamic properties by means of a power series expansion of the partition function about $T = 0$°K. This expansion has been found to be possible even though the ground state is degenerate because of the existence of a substantial amount of "partial long-range order." Expressions for the zero field magnetic susceptibility and the specific heat are derived.

24,237 THERMODYNAMIC GREEN'S FUNCTIONS OF AN ISOTROPIC AN FERROMAGNET WITH ARBITRARY SPIN by J. Czerwonko (Joint Inst. of Nuc

udies); Soviet Phys.-Solid State, Vol. 5, pp. 1560-1565, Feb. 1964

e equations for Green's functions of an isotropic antiferromagnet with arbiry spin in a longitudinal and transverse magnetic field are analyzed. All derived equations are valid for both low and high temperatures, and they n also be used for ferromagnets if appropriate changes are made. The equans obtained for magnetization are solved for low and near-critical temperaes. In the latter case a solution is also obtained for ferromagnets.

,238 MAGNETIC FIELD QUENCHING OF THE SUHL-NAKAMURA WIDTH ANTIFERROMAGNETS by P. Pincus (U. California, Los Angeles); J. Appl. ys., Vol. 35, pp. 839-840, Mar. 1964

a magnetic material, the nuclear spins are coupled via the exchange of virl magnons (Suhl-Nakamura interaction). At low temperatures this interacn is mainly transverse, i.e., $I_i^+ I_j^-$, and is a main contributor to the transrse nuclear relaxation time T_2 in materials with high concentrations of nuear spins. If an external dc field, comparable to the nuclear hyperfine field, applied perpendicularly to the direction of sublattice magnetization in an riferromagnet the indirect interaction tends toward a scalar form. The scalar rt of the interaction has a vanishing second moment and thus does not conbute to the linewidth; in fact, this term gives rise to a small exchange narwing of the NMR line. For the F^{19} resonance in materials, such as FeF_2 where e hyperfine field is only of the order of 40 kg, such a narrowing may be obrvable in moderate fields (~20 kg).

,239 GREEN'S-FUNCTION THEORIES OF ANTIFERROMAGNETISM by F. Anderson and H.B. Callen (U. Pennsylvania); Bull. Am. Phys. Soc., Vol.9, 291(A), Mar. 1964

he thermodynamic properties and the phase-transition curves of antiferromagts with uniaxial anisotropy have been investigated in the random phase apoximation (RPA) and the Callen decoupling approximation (CD). At low temeratures, CD agrees with spin-wave expansions for the sublattice magnetizaons and susceptibilities, the first-order spin-flip transition, and the 2nd-order ip-paramagnetic-transition curves. RPA gives a constant perpendicular susptibility in the antiferromagnetic phase, whereas CD gives a decrease with mperature, as observed for instance in MnF_2. Neither approximation is adeuate in the neighborhood of the Néel temperature. In RPA, the limit of stality of the paramagnetic phase is identical to the Curie temperature of a ferromagnet of equal $|J|$, in close agreement with Padé predictions, whereas CD ives widely different temperatures even for vanishing anisotropy. However, ven RPA becomes internally inconsistent in the antiferromagnetic phase near N.

4,240 A MEASUREMENT OF SPIN-WAVE DISPERSION IN MnF_2 AT 4.2°K y G.G. Low, A. Okazaki, K.C. Turberfield (AE Res. Estab., Harwell), and .W.H. Stevenson (Aberdeen U., Scotland); J. Appl. Phys., Vol. 35, pp. 98-999, Mar. 1964

ntiferromagnetic spin waves have been observed in a single crystal of MnF_2 t 4.2°K by the inelastic scattering of neutrons. Measurements were carried ut using a twin rotor time-of-flight spectrometer having a mean incident neuon wavelength of 3.00 A and a resolution (half-width at half-height) of 0.06 . Spin waves were excited in the {010} plane of the crystal and the dispersion plotted for propagation in the <100> and <001> directions. The observed ispersion curves can be accurately described by spin-wave theory using the llowing values for the parameters concerned: $J_1 = 0.32$°K (ferromagnetic), $_2 = 1.76$°K (antiferromagnetic), $|J| < 0.05$°K, and an anisotropy field at zero ave vector $H_A = 1.06$°K, where J_1 is the exchange coupling between nearest eighbors (in the <001> direction), J_2 acts between next nearest neighbors (<111> directions), and J_3 refers to third-neighbor coupling (along the <100> nd <010> directions). A small effect arising from the wave vector dependence f H_A has been calculated and taken into account in the evaluation of these arameters. The values quoted are in excellent agreement with those in (Mn, Zn)F_2, and from paramagnetic neutron scattering at room temperature.

4,241 THEORY OF SPIN WAVES IN ANTIFERROMAGNETS by G.M. Genin, Yu.A. Otmakhov and E.A. Rosenblyum (Lobachevskii Gor'kov State U.); oviet Phys.-Solid State, Vol. 5, pp. 2172-2178, Apr. 1964

General dispersion relations for a uniaxial antiferromagnet are derived. An nalysis is made of the cases where an external constant magnetic field is parallel or perpendicular to the anisotropy field. It is found that in general it is ot possible to split a wave propagating through an antiferromagnetic medium into spin and electromagnetic waves. In addition to the propagation effects, an analysis which takes into account losses is also carried out.

24,242 THEORY OF RELAXATION PROCESSES IN ANTIFERROMAGNETS HAVING A HELICAL STRUCTURE by M.A. Savchenko and V.G. Bar'yakhtar (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2010-2016, Apr. 1964

An analysis of the exchange interaction between spin waves and conduction electrons at low temperatures in antiferromagnets having helical structure is presented. It is shown that the average probabilities due to the emission and absorption of spin waves by conduction electrons are proportional to T, while the average probabilities of electron scattering by spin waves are proportional to T^4.

24,243 THE MAGNETIC SUSCEPTIBILITY OF MnHg by P. De V. Du Plessis and L. Alberts (U. Orange Free State, So. Africa); Brit. J. Appl. Phys., Vol. 15, pp. 109-111(L), Man. 1964

The preparation and magnetic susceptibility measurements of the intermetallic compound MnHg are described. The material is antiferromagnetic with a Néel point at 198°K. The number of unpaired electron spins, as deduced from paramagnetic measurements, is 3.8 per manganese atom. The magnetic susceptibility was investigated with a Sucksmith balance in the 90-320°K temperature range.

24,244 MAGNETIC ANISOTROPY IN ANTIFERROMAGNETIC CHROMIUM by R.A. Montalvo and J.A. Marcus (Northwestern U.); Phys. Lett., Neth., Vol. 8, pp. 151-153(L), Feb. 1, 1964

Measurements of the temperature and field dependences of the torque acting on a single crystal of chromium in a homogeneous magnetic field are discussed. A four-fold symmetric torque, τ_4, was observed in the [100] direction after a crystal was heated to ~50°C and cooled to a lower temperature with a cooling field $H_c = 0$. For low fields τ_4 is nearly proportional to H^4. With decreasing temperature τ_4 increases to a maximum at 120°K and then falls off rapidly. An additional two-fold symmetric torque τ_2, which is proportional to the cooling field and to the square of the measuring field, was observed on cooling from above the Néel temperature (312°K) in a magnetic field. τ_2 increases with decreasing temperature to a maximum at 120°K, where it abruptly reverses sign and increases in magnitude. Cooling with the field along [010] reverses the sign of the induced torque. Field cooling also produces significant changes in the magnetoresistance and de Haas-van Alphen effect at liquid helium temperature.

24,245 NEUTRON DIFFRACTION STUDY OF MAGNETIC STACKING FAULTS IN ANTIFERROMAGNETIC K_2NiF_4 by R. Plumier (C.E.N. Saclay, France); J. Appl. Phys., Vol. 35, pp. 950-951, Mar. 1964

The unusual width of the (101) and (102) magnetic reflections of antiferromagnetic K_2NiF_4 shows the existence of stacking faults in the piling up of the antiferromagnetic sheets. The probabilities of such faults at various temperatures are determined and show an increase with temperature. It is then shown that lowering of the free energy is obtained by considering exchange striction from a slight orthorhombic distortion; ungrouped stacking faults lead to an additional lowering of the free energy.

24,246 ANTIFERROMAGNETIC TRANSITION IN γ-PHASE Mn ALLOYS by J.E. Zimmerman, A. Arrott, H. Sato and S. Shinozaki (Ford Motor Sci. Lab.); J. Appl. Phys., Vol. 35, pp. 942-943, Mar. 1964

Specific heat measurements on Mn-rich Mn-Cu alloys reveal first-order antiferromagnetic phase transitions at around room temperature and above. Magnetic entropy increases with Mn content but in all alloys it is smaller than would be expected from localized spins. The same is true of an equiatomic FeMn alloy. However, the specific heat exhibits a well-defined cusp at 475°K, indicating a transition of second or higher order. By extrapolating the Mn-Cu results to pure Mn, the thermodynamic properties of γ-Mn in the region of the transition are derived.

24,247 A PROTON RESONANCE STUDY OF THE MAGNETIC STRUCTURE OF ANTIFERROMAGNETIC $CoCl_2 \cdot 6H_2O$, $CoBr_2 \cdot 6H_2O$, $NiCl_2 \cdot 6H_2O$ AND $NiBr_2 \cdot 6H_2O$ by R.D. Spence, P. Middents, Z. ElSaffar and R. Kleinberg (Michigan State U.); J. Appl. Phys., Vol. 35, pp. 854-855, Mar. 1964

Studies of the antiferromagnetic states of $CoCl_2 \cdot 6H_2O$, $CoBr_2 \cdot 6H_2O$, $NiCl_2 \cdot 6H_2O$, and $NiBr_2 \cdot 6H_2O$ by proton resonance show that their magnetic space group must be either $P_c 2_1/a$ or $C_c 2/c$. The magnitudes of the local fields indicate that the Co salts belong to the former group and the Ni salts to the latter.

Antiferromagnetic:
Gd_4Se_3 - See 24,127
$FeNaO_2$, $GeNi_2O_4$, Cr_3S_4, Cr_3Se_4 and Cr_3Te_4 - See 24,096
Eu-Chalcogenides, -Halogens and -Silicates - See 24,125

ANTIFERRO- AND ANTIFERRIMAGNETIC RESONANCE

24,248 THEORY OF ANTIFERROMAGNETIC RESONANCE ABSORPTION IN CoF_2 by H. Kamimura (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 844-846, Mar. 1964

The effective spin Hamiltonian for the interaction between the fictitious spins

of the lowest Kramers doublets in CoF_2 is derived. The spin-wave spectra are then derived for a two-sublattice model in which the spins point along the ±c directions. Only one antiferromagnetic resonance frequency is obtained in the absence of magnetic field. In the presence of a magnetic field applied along the c axis the resonance line is split into two. In CoF_2 the anisotropy arising from the crystal field has an important effect on the magnitude of the resonance frequency. The discrepancies between this theory and recent experiments suggest that several other mechanisms, which are pointed out, should be considered.

24,249 ANTIFERROMAGNETIC RESONANCE LINEWIDTH IN MnF_2 NEAR THE TRANSITION TEMPERATURE by J.C. Burgiel and M.W.P. Strandberg (MIT); J. Appl. Phys., Vol. 35, pp. 852-853, Mar. 1964

The antiferromagnetic resonance (AFMR) linewidth of MnF_2 has been studied near the Néel temperature T_N. In the presence of an applied magnetic field, the linewidth diverges as $|T-T_N|^{-5/6}$. In the absence of an applied field, the linewidth is larger and diverges approximately as $|T-T_N|^{-4/3}$. The linewidth is independent of magnetic field direction and is the same for both branches of the AFMR spectrum. Near T_N the AFMR frequency varies as $|T-T_N|^{0.483\pm0.025}$ whereas the simplest molecular field theory predicts a $|T-T_N|^{1/2}$ variation. From this temperature dependence, together with existing data on the fluorine nuclear magnetic resonance in MnF_2, we find that the anisotropy energy E_A is proportional to $M^{2.89\pm0.16}$ compared to Zener's M^3 and Oguchi's $M^{2.9}$ theoretical results. Above T_N, the electron paramagnetic resonance in MnF_2 has been observed. For $H_0 \parallel c$ the linewidth varies as $(T-T_N)^{-3/8}$ near T_N. For $H_0 \perp c$ the linewidth increases more slowly as T_N is approached.

Proton:
Magnetic Resonance in $CoCl_2 \cdot 6H_2O$ - See 24,103
Resonance in $CoCl_2 \cdot 6H_2O$, $CoBr_2 \cdot 6H_2O$, $NiCl_2 \cdot 6H_2O$ and $NiBr_2 \cdot 6H_2O$ - See 24,247

24,250 ANTIFERROMAGNETIC RESONANCE IN CoF_2, NiF_2, AND $MnCO_3$ by P.L. Richards (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 850-851, Mar. 1964

The far-infrared transmission spectra of CoF_2, NiF_2 and $MnCO_3$ have been measured from 3 to 100 cm^{-1} using the techniques of Fourier-transform interferometry. Antiferromagnetic resonance branches have been found in CoF_2 at 28.5 cm^{-1} and 36 cm^{-1} at temperature $T \approx 0$, each of which splits in a magnetic field along the c axis. These resonances have been studied as a function of field, temperature, and uniaxial stress. Antiferromagnetic resonance at 31.1 cm^{-1} and ferromagnetic resonance at 3.33 cm^{-1} in NiF_2 at $T \approx 0$ have been studied as a function of field and temperature, and the results are compared with Moriya's theory. Antiferromagnetic resonance has been observed at 4.13 cm^{-1} in $MnCO_3$ at $T \approx 0$.

24,251 FAR INFRARED ANTIFERROMAGNETIC RESONANCE IN MnO AND NiO by A.J. Sievers, III and M. Tinkham (U. California, Berkeley); 1963, 25 pp.; U.S. Gov. Res. Rep., Vol. 39, pp. 65-66(A), Mar. 5, 1964
AD 419 634 OTS $2.60

The uniaxial dipolar anisotropy in antiferromagnetic MnO and NiO aligns the two opposing sublattice moments in an easy (111) plane. The two normal modes for small oscillations of the sublattice magnetizations about a preferred direction within this plane are both nondegenerate and linearly polarized. The high frequency mode has been observed at low temperatures (2°K) at 27.5 and 36.6 cm in MnO and NiO, respectively. In agreement with the unobservably small second-order Zeeman shift expected for these nondegenerate modes, a 10.7 koe field was found to have no effect on the observed resonance frequencies. Increasing the sample temperature decreases the frequency of the mode in each case.

24,252 ZERO-FIELD ^{55}Mn NMR IN ANTIFERROMAGNETIC MnF_2 by K.B. Jefferts and E.D. Jones (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 225(A), Mar. 1964

The zero-field NMR of ^{55}Mn has been observed directly in the antiferromagnetic state of MnF_2. A single resonance, with linewidth ~1.3 Mc/sec, was observed in the frequency range of 650-675 Mc/sec and the temperature range of 1.5°-20.5°K. The extrapolated NMR frequency at 0°K is found to be 671.4 ± 0.2 Mc/sec. The dipolar field at the ^{55}Mn site is calculated to be $H_{dip} = +5.770$ koe. Combining the 0°K ^{55}Mn NMR frequency with the measured hyperfine-coupling constant, $^{55}A = -(90.78\pm0.3) \times 10^{-4}$ cm^{-1}, for Mn^{2+} in ZnF_2, gives a value for the zero-point spin deviation of $1-\langle S\rangle/S = (0.43\pm0.34)$ per cent, where for the fully aligned state $\langle S\rangle = S = 5/2$. The experimental zero-point spin deviation is to be compared with the theoretical value predicted by spin-wave theory of 2.37 per cent. The observed temperature dependence of the ^{55}Mn NMR frequency agrees, within experimental error, with the measured temperature dependence of the ^{19}F NMR in antiferromagnetic MnF_2. Contributions to the ^{55}Mn NMR linewidth are discussed.

24,253 Mn^{55} NUCLEAR MAGNETIC RESONANCE IN ANTIFERROMAGNETIC $RbMnF_3$ by A.J. Heeger and D.T. Teaney (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 846-847, Mar. 1964

The observation and study of the Mn^{55} nuclear magnetic resonance in antiferromagnetic $RbMnF_3$ at low temperatures are reported. The direct detection is possible because of a large enhancement of the signal from one of the NMR modes in a low anisotropy antiferromagnet above the critical field for spin flopping. Large frequency pulling effects are observed, and found to be in excellent quantitative agreement with theory. The unpulled NMR frequency has been determined as 687 Mc/sec at 2°K, and the corresponding linewidth is 60 kc/sec. An anomalous increase in linewidth with decreasing field and temperature is described.

24,254 DIRECT Mn^{55} NMR ABSORPTION IN ANTIFERROMAGNETIC KMnF by A. Nakamura, V. Minkiewicz and A.M. Portis (U. California, Berkeley); J. Appl. Phys., Vol. 35, pp. 842-843, Mar. 1964

The direct observation of Mn^{55} nuclear magnetic resonance absorption in the nearly cubic antiferromagnetic $KMnF_3$ is reported. The striking features of the resonance are its unusual intensity and its strong temperature and field dependence. Both effects are associated with the strong coupling between nuclear and electronic modes in magnetic materials with low anisotropy and large nuclear magnetization. The nuclear linewidth at 4.2°K is 740 kc/sec between points of half-maximum absorption. This width is in agreement with that expected from the Suhl-Nakamura indirect coupling between nuclear spins. At lower temperatures the linewidth increases greatly, approaching nearly 3 Mc/sec at 2.1°K. This unexpected increase in linewidth is attributed to a low-temperature inhomogeneity in the antiferromagnetic excitation spectrum.

24,255 NUCLEAR ANTIFERROMAGNETIC DOUBLE RESONANCE IN MnCO by D. Shaltiel and H.J. Fink (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 848-849, Mar. 1964

The resonance of the low-frequency branch of $MnCO_3$ shows that the anisotropy field in the (111) plane consists of an approximate temperature-independent term equal to 0.98 ± 0.04 G and a temperature-dependent term equal to $(8.6 \pm 0.3)/T_n$. The temperature-dependent anisotropy field originates from the hyperfine interaction and is proportional to the nuclear polarization which is inversely proportional to the nuclear spin temperature T_n. The nuclei form two sublattices that are coupled antiparallel to the electronic sublattices. This coupling shifts the nuclear frequency from that calculated from its hyperfine field by a factor proportional to the nuclear polarization. At 4.2°K the nuclear resonance at 538 Mc/sec was observed by measuring its effect on the electron resonance. It is 102 Mc/sec lower than the frequency expected if the nuclear and electron system are decoupled. For intermediate nuclear power levels two electron resonances were observed at 6 Gc/sec. One of the lines corresponds to the unshifted resonance line; the position of the other line was dependent on the nuclear frequency only. This shift is due to partial saturation of the nuclear spin system which saturates at about 640 Mc/sec.

Antiferromagnetic Resonance in CoO - See 24,086

PARAMAGNETISM

24,256 CONTRIBUTION OF LINE DEFECTS TO THE PARASITIC PARAMAGNETISM IN THE APPROACH TO MAGNETIC SATURATION by A. Aharoni (Weizmann Inst. Sci., Rehovoth, Israel); J. Appl. Phys., Vol. 35, pp. 913-914, Mar. 1964

For one-dimensional plane defects, a parasitic paramagnetism is obtained if in the near vicinity of each defect there are defects of opposite sign. The two-dimensional problem of a line defect surrounded by defects of opposite sign, is approached by assuming that the transverse magnetization vanishes on a certain circle around the defect. For such a model one obtains a magnetic hardness term, when the radius of the circle is large compared to the fall-off distances of the disturbance in the material. For a radius much smaller than the fall-off distances, a parasitic paramagnetism term is obtained, with apparent reduction in the saturation magnetization value.

24,257 PARAMAGNETIC SUSCEPTIBILITY OF Eu_2O_3 FROM 300° TO 1300°K by S. Arajs and R.V. Colvin (Bain Lab., U.S. Steel); J. Appl. Phys., Vol. 35, pp. 1181-1183, Apr. 1964

The magnetic susceptibility of Eu_2O_3 has been studied as a function of temperature between 300° and 1300°K. The results can be satisfactorily explained by the Van Vleck theory of paramagnetism with Judd's energy levels of free Eu^{3+} ions.

,258 MAGNETIC SUSCEPTIBILITY OF SEMICONDUCTING ELEMENTS OF OUP IV DETERMINED ON THE BASIS OF X-RAY ANALYSIS by N.N. ota and A.U. Sheleg (Acad. Sci. BSSR); Soviet Phys.-Doklady, Vol. 8, pp. 7-889(L), Mar. 1964

e diamagnetic and paramagnetic components of the magnetic susceptibilities diamond, silicon, germanium and gray tin have been determined on the is of X-ray analysis of the electron distributions. The results show that the olute values of the two components are similar and that they increase in the ler of the series C-Si-Ge-a-Sn, while the total value of the susceptibility ses through a minimum at the value for Si.

,259 EFFECT OF CRYSTAL LATTICE DEFECTS ON THE MAGNETIC SUS-PTIBILITY OF PARAMAGNETIC METALS by I.Ya. Dekhtyar and V.S. Mik-enkov (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 2193-96, Apr. 1964

e effect of imperfections in the crystal structure, produced by quenching and astic deformation, on the magnetic susceptibility of paramagnetic metals is cussed. It is found that these defects change the magnetic susceptibility by amount which can be determined experimentally. The experiments show that enching increases the paramagnetic susceptibility of platinum, while plastic formation increases the susceptibility of niobium and copper containing 10 cent nickel, decreases the susceptibility of molybdenum and has no effect the susceptibility of platinum.

,260 SUPERPARAMAGNETISM IN MAGNETICALLY DILUTE SYSTEMS by Ishikawa (Lab. Electrostat. et Phys. Metal, Grenoble, France); J. Appl. ys., Vol. 35, pp. 1054-1059, Mar. 1964

perparamagnetic behavior observed in magnetically dilute systems is discussed. e clusters that behave like superparamagnetic fine particles are ferromagnet- or ferrimagnetic regions separated magnetically from the matrix, because ese regions are surrounded by nonmagnetic atoms. The magnetic properties of ute oxide systems such as: 0.9 $ZnFe_2O_4$-0.1 $NiFe_2O_4$; 0.9 $FeTiO_3$-0.1 Fe_2O_3; d $Y_{1.5}Ca_{1.5}Fe_{4.5}Sn_{1.5}O_{12}$ are better understood if the existence of the super-ramagnetic clusters is taken into account. The Langevin function type mag-tization curves observed for the Fe-Cr alloys in the composition range where rromagnetism just disappears, however, were found not to have the character-ics of superparamagnetism, although superparamagnetic clusters are predicted the localized model.

,261 OBSERVATION OF SUPERPARAMAGNETISM BY MÖSSBAUER EFFECT W.J. Schuele (Franklin Inst.), S. Shtrikman and D. Treves (Weizmann Inst.); ll. Am. Phys. Soc., Vol.9, p. 226(A), Mar. 1964

ssbauer spectra of ^{57}Fe in ultrafine $NiFe_2O_4$ and $CoFe_2O_4$ were studied as a nction of crystallite size. A transition from a 6-line to a doublet was observ- with decreasing size with a corresponding change of the hyperfine field from out 0.5 to 0 mg. At room temperature, the transition occurred for a size of 0 and 130 A for $NiFe_2O_4$ and $CoFe_2O_4$, respectively. The transition was in-rpreted as a "motional narrowing" due to onset of superparamagnetism. A wer limit of 10^9 cps could be estimated for f_0 in the relation for the electron-in-relaxation time $\tau = (\exp Kv/kT)/f_0$. Here, K is the anisotropy per unit lume, v crystallite volume, k Boltzman's constant, and T absolute tempera-re. As expected, the transition size was found to decrease at liquid-air tem-rature.

ramagnetic $Eu_{0.5}Gd_{1.6}Se_{2.9}$ - See 24,127

PARAMAGNETIC RESONANCE

4,262 THEORY OF SPIN RESONANCE AND RELAXATION by P.N. Argyres d P.L. Kelley (Lincoln Lab.); Phys. Rev., Vol. 134A, pp. A98-111, Apr. 6, 964

quantum-statistical-mechanical theory of spin resonance and relaxation is resented which avoids the assumptions of earlier theories, is capable of ex-nsion to other than the lowest Born approximation for the strength of the re-xation mechanism, and is applicable over a broader range of physical situa-ons. From the Liouville equation for the combined system of spin+bath, the eory yields a non-Markoffian equation for the time development of the sta-stical density operator for the spin system alone. Detailed consideration is iven to the response of the spin system linear in the driving field, and an quation for the steady-state spin density operator is deduced. A simple appli-ation exemplifies the new features of the theory and it is shown that it describes he phenomenon of "motional" narrowing. The response to an arbitrary external ield is studied with particular reference to the problem of approach to thermal quilibrium and the phenomenon of spin resonance saturation. The latter is con-idered in some detail for a system of independent spins, for which an equation or the steady-state magnetization is derived and discussed.

24,263 INTENSITY OF ALLOWED AND FORBIDDEN ELECTRON PARAMAGNETIC RESONANCE LINES by G.L. Bir (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1628-1635, Feb. 1964

Expressions for the probabilities of various hyperfine transitions are obtained. For a small crystal field, the characteristics of the electron spectrum are calculated by perturbation theory. It is shown that if hyperfine interaction and a crystal field are present, the electron paramagnetic resonance line intensities have strong angular dependence.

24,264 A 1.2 cm EPR SPECTROMETER AND PARAMAGNETIC RESONANCE IN SOME COPPER SALTS by U.S. Ghosh, R.N. Bagchi and A.K. Pal (Indian Assoc. Cultivation of Sci., Calcutta); Indian J. Phys., Vol. 37, pp. 555-567, Nov. 1963

A transmission type EPR spectrometer operating at 1.28 cm wavelength is described. Resonance absorption signals at room temperature for some concentrated paramagnets have been obtained with a small noise-to-signal ratio. Orthorhombic g-values and orientations of the tensor ellipsoid of single crystals of $CuK_2(SO_4)_2 \cdot 6H_2O$ have been determined at room temperature and some features of EPR spectra of two copper salts are discussed.

24,265 SPIN RESONANCE IN F_2-CENTERS IN ALKALI-HALIDE CRYSTALS by Yu.V. Chkhartishvili (Tbilis State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1733-1734(L), Feb. 1964

The energy levels of an F_2-center are calculated numerically. The result shows that the energy of the triplet state is lower than the energy of the singlet state, so that the electron spins of two F-centers which form a single F_2-center are parallel. This fact makes it possible to observe the spin resonance in the F_2-center.

24,266 SPIN-LATTICE INTERACTION EXPERIMENTS ON COLOR CENTERS IN QUARTZ by A.L. Taylor and G.W. Farnell (McGill U., Montreal); Canadian J. Phys., Vol. 42, pp. 595-607, Apr. 1964

The paramagnetism of the color centers in smoky quartz is caused by the electron which is missing from a nonbonding oxygen orbital near an aluminum impurity. The effects produced by externally introduced microwave phonons on the spin-resonance signal from these color centers have been studied in detail as a function of the relative phonon and spin-resonance frequencies, the phonon power, the spectrometer power, the magnetic field angle, and the phonon polarization. As has been noted previously, these interactions do not conform with those observed in other paramagnetic crystals. Effects of an applied electric field on the resonance lines and various further experiments on the color centers in smoky quartz are reported; two in particular suggest that the "hole", the missing electron, makes thermally excited transitions between two different sites adjacent to a given impurity atom. One of the experiments is a measurement of the cross relaxation which takes place between the various lines of the spectrum, while the other is a measurement of the low-frequency dielectric loss found at liquid helium temperatures. An attempt is made to discuss the spin-phonon results in terms of such transitions for the holes.

24,267 ELECTRON SPIN RESONANCE EXPERIMENTS ON SHALLOW DONORS IN GERMANIUM by D.K. Wilson (Bell Labs.); Phys. Rev., Vol. 134A, pp. A265-286, Apr. 6, 1964

At liquid helium temperatures, spin resonance of localized donor electrons has been observed in phosphorus-, arsenic-, and bismuth-doped germanium. The presence of hyperfine splitting confirms the singlet as the ground state for all three. The separation of the excited triplet states has been measured by uniaxially stressing the samples. The triplet states are all found to lie close to the effective-mass value of 0.009 ev. The anisotropy of the g tensor has also been measured by uniaxial stress measurements giving a value for the g anisotropy $g_{\parallel} - g_{\perp} = -1.05$ for arsenic-doped germanium. The large g anisotropy gives rise to an anisotropic linewidth which is caused by built-in strains in the crystal. Measurements show a strong correlation of this line broadening with the number of dislocations. The broadening is larger than predicted as a result of condensation of the impurities in the neighborhood of dislocations. The linewidth for magnetic fields in the [100] direction, where strain broadening of the line vanishes, has been shown to arise from unresolved hyperfine interactions with Ge^{73} nuclei. The linewidths are in good agreement with values calculated using an isotropic approximation to the effective-mass wave function. The spin-lattice relaxation times have been measured and compared with the theory of Roth and Hasegawa for the one-phonon process. The temperature dependence, the dependence on amplitude and orientation of the magnetic field, and effects of strain predicted by their theory were observed.

24,268 BROADENING OF PARAMAGNETIC RESONANCE LINES DUE TO INDIRECT EXCHANGE INTERACTIONS by S.A. Al'tshuler and R.M. Mineeva (Ul'yanov-Lenin Kazan' State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1234-1235, Dec. 1963

It is shown that isotropic exchange forces may make the main contribution to the width of the paramagnetic resonance lines if the spin levels are split by the

crystal field. Results of the calculated linewidth by the method of moments agree well with experimental data for the case of ruby.

24,269 DISCUSSION OF SPIN-SPIN RELAXATION FORMULAE AND EXPERIMENTS by R.L. Peterson (NBS); Phys. Lett., Neth., Vol. 8, pp. 158-159(L), Feb. 1, 1964

Corrections to the Caspers formula for describing spin-spin relaxation and to the Hartmann-Anderson modification of the Caspers formula are discussed. Corrected values of the constant a of the Caspers formula, determined by using the g-tensor g = 2.2, are given for the three cases considered by Caspers. For the Hartmann-Anderson modification, in which Caspers' formula is multiplied by the factor $H_L^2/(2H^2 + H_L^2)$, where H_L is an internal field defined only in terms of the part of the spin-spin Hamiltonian which commutes with the Zeemar term, a corrected value for H_L^2 ($H_L^2 = 21 \times 10^4$ oe^2) is given. Using this value, the electronic spin-spin relaxation data of Locher and Verstelle for the Tutton salt $Cu(NH_4)_2(SO_4)_2 \cdot 6H_2O$ can be fitted by $\tau = [H_L^2/(2H^2 + H_L^2)]$ 2.8 exp $(H^2/57 \times 10^4)$ ns. The formulae are also applied to recent data on nuclear spin-spin relaxation.

24,270 SECOND MOMENT OF ELECTRON PARAMAGNETIC RESONANCE LINES IN RUBY by D.N. Klyshko (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2066-2068, Apr. 1964

The shape of the electron paramagnetic absorption lines in ruby crystals containing ion concentrations of 0.02, 0.1 and 0.5 per cent has been investigated. The measured values of the second moment of the lines are two orders of magnitude less than the theoretical values. A simple method for taking account of the strong exchange interaction in the calculation of absorption-line moments is discussed.

24,271 PARAMAGNETIC RELAXATION OF THE Fe^{3+} ION IN CORUNDUM by N.E. Kask, L.S. Kornienko and A.I. Smirnov; Soviet Phys.-Solid State, Vol. 5, pp. 1212-1215, Dec. 1963

Paramagnetic relaxation of the Fe^{3+} ion in corundum has been investigated by the pulse-saturation method. The spin-lattice relaxation time τ_1 measured in the temperature interval 2-80°K shows that in the range 5-15°K, τ_1 is essentially independent of temperature. The effect of spin cross relaxation on the measurement is discussed. In a certain frequency range, the presence of cross relaxation shortens the relaxation time τ_1.

24,272 LINESHAPES OF PARAMAGNETIC RESONANCES OF CHROMIUM IN RUBY by W.J.C. Grant (MIT); Bull. Am. Phys. Soc., Vol.9, p. 244(A), Mar. 1964

Numerical calculations were performed for the lineshapes of paramagnetic resonances of Cr in ruby. Not only half-widths and intensities but the fine details of the lineshapes are accounted for over a concentration range of about 0.01 per cent-1 per cent. In particular, it was found that (1) the dipolar line departs only slightly from the Lorentzian at the highest attainable concentrations, (2) the line is predominantly nondipolar at low concentrations, (3) no inference is possible from moments as to the magnitude or parametric behavior of intensities and half-widths, (4) neither exchange nor clustering of impurities affect the lineshape at low concentrations, and (5) exchange cannot narrow the $(\frac{1}{2}, -\frac{1}{2})$ transition.

24,273 SPIN-LATTICE RELAXATION OF THE Ti^{3+} ION IN CORUNDUM by N.E. Kask, L.S. Kornienko, T.S. Mandel'shtam and A.M. Prokhorov (Lomonosov Moscow State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1677-1679, Feb. 1964

A study of the spin-lattice relaxation of the Ti^{3+} ion in corundum by the pulse-saturation method is reported. The temperature dependence was determined in the interval 1.7-3.5°K, from which the distance to the next higher level was estimated to be 30±3 cm^{-1}. The dependence of the relaxation time on the crystal orientation in an external magnetic field was calculated, and the results are in good agreement with experiment.

24,274 SPIN-LATTICE RELAXATION OF Fe^{3+} IN TmGa AND TmAl GARNETS by R.W. Bierig and L. Rimai (Raytheon Res. Div.); Bull. Am. Phys. Soc., Vol. 9, p. 260(A), Mar. 1964

The temperature dependence of the spin-lattice relaxation time for a number of transitions of the ^6S ground state of Fe^{3+} in TmGa and TmAl garnets has been investigated between 1.9° and ~10°K at 9.6 kMc/sec. The high-temperature region ($T \gtrsim 4$°K) displays an exponential temperature dependence, the experimentally determined splitting being 60±10 cm^{-1}. The low-temperature portion of the temperature dependence does not always follow a 1/T law characteristic of one-phonon relaxation processes. Samples whose Fe^{3+} concentration ranges from ~1 per cent to 0.0005 per cent by weight were investigated.

24,275 SPIN-LATTICE RELAXATION TIME OF Fe^{3+} ION by M.P. Madan (McGill U., Montreal); Canadian J. Phys., Vol. 42, pp. 583-594, Apr. 1964

The spin-lattice relaxation time T_1 of Fe^{3+} ions in iron-rubidium alum $[RbAl(SO_4)_2 \cdot 12H_2O]$, in rutile $[TiO_2]$, and in potassium cobalticyanide $[K_3Co(CN)_6]$ has been measured in the temperature range 1.6°K to 4.2°K a a frequency of 9400 Mc by the pulse saturation technique. For Fe^{3+} in rubid alum, it is found that for crystals having a nominal concentration of 1 per ce and lower the variation of relaxation time with temperature is of the form T_1 $T^{-1.5}$; for higher concentrations the variation is of the form $T_1 \propto T^{-3}$. Cross- relaxation effects are noticed for higher concentrations at all settings of crys tal orientations. For Fe^{3+} in rutile on the average, the relaxation time is ap proximately inversely proportional to temperature, thus indicating the presen of a direct process. There is no significant change in the relaxation time, w the angle of the applied field with the crystal axis is varied. For Fe^{3+} in $K_3Co(CN)_6$, above 2.8°K, it is found that the relaxation time is proportiona to T^{-8}; this is consistent with a two-phonon interaction process (Raman). It is not believed that at the lowest temperature used in this experiment relaxatio is taking place through a single-phonon process (direct).

24,276 DIPOLAR INTERACTION IN SELECTED PARAMAGNETIC CRYSTAL by J. Vanier (McGill U., Montreal); Canadian J. Phys., Vol. 42, pp. 494- 503, Mar. 1964

Broadening of the paramagnetic resonance lines of Cr^{3+} in each of two salts, rubidium alum and potassium cobalticyanide, has been measured as a functio of concentration. In rubidium alum the width between the peaks of the deriv tive was 6.3 oe up to 0.5 per cent and increased with concentration above t value. In $K_3Co(CN)_6$ the width increased with increasing concentration from 2.4 oe at the lowest concentration of 0.01 per cent. Calculations indicate t a major portion of the observed widths is due to dipolar interactions of the C with neighboring nuclei and other Cr^{3+} ions. The greater width observed for nominal $(1/2 \pm 3/2)$ lines over the $(1/2 - 1/2)$ line in every sample at every orientation may be associated with concentration-dependent crystalline impe fections.

24,277 MAGNETIC FIELD DEPENDENCE OF PARAMAGNETIC RELAXATIO IN A KRAMERS SALT by D.A. Davids and P.E. Wagner (Johns Hopkins U.); Phys. Rev. Lett., Vol. 12, pp. 141-142(L), Feb. 10, 1964

Experimental verification that an ensemble of paramagnetic ions in a nonmag netic crystal and a magnetic field H attains thermal equilibrium with a char- acteristic time, T_1, inversely proportional to H^4 is presented. Relaxation rate were measured in a $K_3Co(CN)_6$ sample containing 0.24 at. per cent Fe in mag netic fields of 1100 to 3700 gauss and at temperatures between 2.16 and 1.38 The experimental data are satisfied by the function $1/T_1 = CH^n T + 4.3 \times 10^{-3}$ (sec^{-1}), with $3.88 \leq n \leq 4.06$ and C a proportionality constant.

24,278 RELAXATION PROCESSES IN THE PARAMAGNETIC RESONANCE O Gd^{3+} IN CaF_2 by A.A. Manenkov and Yu.E. Pol'skii (Acad. Sci. USSR); Soviet Phys.-JETP, Vol. 18, pp. 985-987, Apr. 1964

The relaxation processes of Gd^{3+} ions in the fluorite lattice have been studie at 9370 Mc/sec and at liquid helium temperatures by the pulse saturation met od. The relaxation times for ions in a tetragonal or trigonal field depend wea ly on the temperature, and the relaxation time depends weakly on the symmet of the crystal field. The spin-spin cross-relaxation effects are discussed; cross relaxation times were measured at ion concentrations of 3×10^{-4} and 5×10^{-4}

24,279 TEMPERATURE DEPENDENCE OF PARAMAGNETIC RESONANCE LINES by I. Svare and G. Seidel (Harvard U.); Phys. Rev., Vol. 134A, pp. A172-186, Apr. 6, 1964

Changes in the position and shape of paramagnetic absorption lines of Nd^{3+} ir neodymium ethyl sulfate, Ni^{2+} in nickel fluosilicate, and Cu^{2+} in copper po- tassium sulfate have been observed at 30 kMc/sec in the temperature range fro 0.4 to 4.2°K. The observed shifts are compared to first and second line moments calculated from spin-spin interactions when the average populations of the spin levels are weighted by the proper Boltzmann factors. In this manner i is possible to determine the magnitude and sign of the exchange interaction $\mathcal{H}_{ij} = AS_i \cdot S_j$ between spins. A ferromagnetic interaction $A = -(3.9 \pm 0.4 \times 10^{-18}$ erg was found between nearest-neighbor Ni^{2+} ions in $NiSiF_6 \cdot 6H_2O$ with no evidence of anisotropic exchange. Nearest-neighbor spins at similar lattic positions in $K_2Cu(SO_4)_2 \cdot 6H_2O$ appear to be coupled by an exchange interactio of approximately $A = 9 \times 10^{-18}$ erg, while the exchange between the two neigh boring dissimilar Cu^{2+} ions in the unit cell is $A = -1.4 \times 10^{-18}$ erg. Evidence for a weak anisotropic and antiferromagnetic coupling in $Nd(C_2H_5SO_4)_3 \cdot 9H_2O$ is presented. Magnetostatic modes were observed in copper salts at low tempe ature, and this effect is briefly discussed in relation to the present type of ex- periment.

24,280 EVIDENCE FOR AN ISOTROPIC SHIFT IN THE ELECTRON-SPIN-RESONANCE ABSORPTION SPECTRUM OF Fe^{3+} IN CALCITE by S.A. Marshall, J.A. Hodges and R.A. Serway (IIT Res. Inst.); Phys. Rev., Vol. 133A, pp. A1427-1431, Mar. 2, 1964

The hyperfine structure spectrum of trivalent iron located substitutionally for

lcium in calcite has been studied at a wavelength of 3 cm. At 77°K, the perfine splitting tensor of Fe^{57} has been found to be isotropic with a value = (−11.23±0.04) oe. This result was obtained from data taken on seven septe fine structure transitions, five at $\theta = 0$ and two at $\theta = \frac{1}{2}\pi$. An analysis of hyperfine structure components taken at $\theta = 0$ has shown that aside from the t that Fe^{57} has a nuclear spin of $\frac{1}{2}$, its fine structure spectrum is measurably ferent from that of Fe^{56} whose nucleus has zero spin. The difference in the fine structure spectra can be explained by a shift in the crystal-field conants of Fe^{57} with respect to Fe^{56} with no measurable shift in the spectroscopic itting factor. The shifts in B_2^0 and B_4^0 for Fe^{57} using the values for Fe^{56} as ferences are given by $\delta B_2^0 = (2.0\pm0.2) \times 10^{-2}$ oe and $\delta B_4^0 = (-1.3\pm0.7) \times 10^{-4}$ oe. Spectral shifts due to Fe^{54} relative to Fe^{56} have also been detected d found to be opposite in sign and approximately twice the magnitude of the fts due to Fe^{57}. These measurements were repeated at 4.2, 50, and 112°K d to within experimental errors, the results exhibited no temperature dependce.

ramagnetic Resonance:
in EuO - See 24,205
Studies of Irradiated Diamond - See 23,574.

,281 ESR STUDY OF NO_2 AND NO_3 IN IRRADIATED LEAD NITRATE by M. Golding and M. Henchman (University Chem. Lab., Cambridge); Chem. Phys., Vol. 40, pp. 1554-1564, Mar. 15, 1964

ad nitrate crystals have been irradiated with electrons at room temperature d their electron spin resonance spectra examined at 77°K to reveal three ramagnetic species. One species shows no hyperfine structure and has an isopic g tensor with a g value at the free spin value: little can be said of its ture. The others are located, by their spectral anisotropy, at nitrate sites in e crystal with the axes of their axially symmetric g tensors parallel to the trate triad axes. One of these species is interpreted as NO_3: it shows no nigen hyperfine structure but a slight interaction with ^{207}Pb. The other is iden-ied as NO_2 rotating in the plane of the nitrate site. Theoretical predictions e in accord with these assignments. Various conclusions are drawn for the diation chemistry. Other species than the NO_2^- and O_2, revealed by chemial analysis, are significant products. The particular lattice determines the ture of these products, their stability and, in the case of NO_2, its mechanism formation. The annealing kinetics of NO_2 and NO_3 differ from that of the O_2^-: Mechanisms previously postulated for the latter are almost certainly too mple.

4,282 ELECTRON SPIN RESONANCE OF GAMMA-RAY IRRADIATED SINLE CRYSTALS OF SODIUM NITRITE by J. Tateno and K. Gesi (Japan AE s. Inst., Ibaraki-ken); J. Chem. Phys., Vol. 40, pp. 1317-1321, Mar. 1, 964

ngle crystals of sodium nitrite were irradiated with Co^{60} gamma rays of about ^{9} R at room temperature and studied by ESR methods. The spectrum consists of triplet and a quintet associated with different paramagnetic species; the forer is believed to be NO_2 and the latter $N_2O_4^-$. From the analysis of the anitropy of the hyperfine tensor the molecular plane of NO_2 lies in the crystal c plane, being different from the result obtained with irradiation at 77°K by eldes and Livingston. Molecular orbital of the unpaired electron of $N_2O_4^-$ as also calculated.

4,283 ELECTRON PARAMAGNETIC RESONANCE OF PHOTOSENSITIVE RON TRANSITION GROUP IMPURITIES IN ZnS AND ZnO by W.C. Holton, . Schneider and T.L. Estle (Texas Instr.); Phys. Rev., Vol. 133A, pp. A1638-641, Mar. 16, 1964

he photosensitive iron transition group impurities Fe, Ni, and V in cubic ZnS nd Ni in ZnO have been studied by electron paramagnetic resonance. The harge states Fe^{3+}, Fe^{+}, Ni^{3+}, and V^{3+} were observed after excitation with ltraviolet light, and, in the case of Ni^{3+}, after excitation with blue light. he magnetic properties are those to be expected for a $3d^7$ (Fe^+ and Ni^{3+}) and $3d^2$ (V^{3+}) configuration in tetrahedral coordination. The quantitative features f the spectra reflect the systematic variations produced by covalency.

4,284 ESR STUDY OF Cu^{2+} AND Mn^{2+} IN $Zn_2P_2O_7$ by C. Calvo, J.G. hambers and W.R. Datars (McMaster U.); Bull. Am. Phys. Soc., Vol.9, p. 44(A), Mar. 1964

he ESR spectra of Mn^{2+} and Cu^{2+} in $Zn_2P_2O_7$ has been studied between room emperature and 200°C. A first-order phase transition is found at 132°C and a ransition of higher thermodynamic order occurs near 155°C. The space group f $Zn_2P_2O_7$ is determined to be C-2/m above 155°C and C-m between 132° nd 155°C. The value of D in the spin Hamiltonian for Mn^{2+} ranges with temperature from 612-1103 G with nearly isotropic g values. The g values of Cu^{2+} how the expected anisotropy along the Z direction and nearly axial symmetry n the x,y plane. The spectral lines of $Zn_2P_2O_7$:Mn^{2+} are broadened near the upper phase transition, with this broadness dependent upon the particular electronic transition involved. These phenomena are associated with the mechanism for the phase transition.

24,285 MAGNETIC RESONANCE IN SIMPLE ELECTRON LEVELS OF INTERSTITIAL V^{3+} IONS IN THE CORUNDUM LATTICE by R.M. Mineeva (Ul'yanov-Lenin Kazan State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1020-1022, Nov. 1963

The spectrum, intensity and linewidth due to transitions between hyperfine sublevels of the lower nondegenerate level of the interstitial V^{3+} ion in the corundum lattice are calculated. It is shown that the linewidth decreases exponentially with decreasing temperature and at $T \approx 1°K$ is one order of magnitude smaller than the spacing between the resonance absorption lines. The result of calculation shows that this material is quite suitable for observing the paramagnetic resonance due to the transitions mentioned above.

24,286 PARAMAGNETIC RESONANCE OF VANADIUM IN AMORPHOUS AND POLYCRYSTALLINE GeO_2 by I. Siegel (Owens-Illinois Tech. Ctr.); Phys. Rev., Vol. 134A, pp. A193-197, Apr. 6, 1964

The X-band electron paramagnetic resonance absorption spectra of vanadium-doped amorphous and polycrystalline tetragonal GeO_2 have been observed at room temperature. The spectrum of the amorphous GeO_2, attributed to VO^{++}, can be described by $g_{\parallel} = 1.929\pm0.001$, $g_{\perp} = 1.976\pm0.001$, $|A_{\parallel}| = (175.5 \pm 0.1) \times 10^{-4}$ cm^{-1}, and $|A_{\perp}| = (68.2\pm0.1) \times 10^{-4}$ cm^{-1}. In the tetragonal GeO_2, the vanadium appears as V^{4+} with spectrum constants $g_z = 1.963_2\pm0.0003$, $g_x = 1.921_3\pm0.0006$, $g_y = 1.921_3\pm0.0001$, $|A_z| = (134.36\pm0.02)\times10^{-4}$cm^{-1}, $|A_x| = (36.69\pm0.01) \times 10^{-4}$ cm^{-1}, and $|A_y| = (37.54\pm0.01) \times 10^{-4}$ cm^{-1}. The spectrum of vanadium-doped polycrystalline hexagonal GeO_2 was not observable at 300 or at 77°K.

24,287 ESR STUDIES OF MgO:V POWDER SAMPLES by N. Mahootian and C. Kikuchi (U. Michigan); Bull. Am. Phys. Soc., Vol.9, p. 245(A), Mar. 1964

Electron-spin-resonance experiments have been performed on MgO powder samples doped with vanadium at about 9 and 17 kMc/sec. Formation of V^{2+} ions as a result of x-irradiation or heating in a reducing atmosphere were studied. It was observed that the ESR spectrum of MgO:V^{2+} ($S = 3/2$; $I = 7/2$) has pronounced dependence on the temperature, as well as the atmosphere under which they have been prepared. The spectrum of the samples that were heated for several hours at about 900°-1000°C in air and X-rayed subsequently consists of a set of 8 sharp lines with a g value of 1.980. Samples heated at about 1200°C and then x-irradiated show an ESR spectrum similar to that of single-crystal samples; i.e., the set of eight central lines are each flanked by two satellites. A third set of samples, heated in a reducing atmosphere such as carbon monoxide or hydrogen at about 1200°C for about 12 hrs, showed an ESR spectrum before x-irradiation. The spectrum, which remains unaffected by X-rays, is identical with samples heated at about 1200°C except for linewidth, presumably due to oxygen vacancies generated by the heat treatment.

24,288 PARAMAGNETIC RESONANCE OF Cr^{3+} IN KYANITE by D.R. Hutton and G.J. Troup (Monash U., Australia); Brit. J. Appl. Phys., Vol. 15, pp.275-280, Mar. 1964

The spin resonance spectra of Cr^{3+} ions in triclinic kyanite Al_2SiO_5 can be interpreted with a spin Hamiltonian containing axial and rhombic terms. There are three magnetically inequivalent sites whose principal magnetic axes are nearly in the (100) crystal plane at angles of approximately -40°, +30°, +50° to the c axis. The measured parameters are $g_{\parallel} = 1.982\pm0.0005$, $g_{\perp} = 1.977 \pm 0.002$ and $|D| = 19.07, 20.85, 15.97$ Gc/s; $E = 0.54, 1.49, 1.04$ Gc/s for the three ions. The inequivalent sites are correlated with the possible substitutional sites available in the crystal.

24,289 PARAMAGNETIC RESONANCE OF AN EXCITED STATE OF THE Cr^{4+} ION IN $CaWO_4$ by R.W. Kedzie, J.R. Shane, and M. Kestigian (Sperry Rand Res. Ctr.); Bull. Am. Phys. Soc., Vol.9, p. 243(A), Mar. 1964

The paramagnetic resonance of the Cr^{4+} ion substituted in the W site has been measured in single crystals of $CaWO_4$ doped only with either naturally occurring Cr or isotopically enriched ^{53}Cr. The spectrum of the even isotopes consists of a single narrow line ($\Delta H = 0.3$ G) that has an intensity maximum at about $T_m = 23°K$. The resonance linewidth increases and the intensity decreases for $T > T_m$ such that the line vanishes above 50°K. An exponential decrease in intensity (I) is observed for $T < T_m$. A plot of ln(I) as a function of $1/T$ yields a straight line having a slope $E/k \simeq 96°K$, where E is the energy difference between the ground state and the excited resonance doublet. The resonances due to the odd isotope consist of four lines arising from an anisotropic hyperfine interaction ($B > A$). The spectrum of both the odd and even isotopes has axial symmetry about the tetragonal C axis. The results can be described by means of a spin Hamiltonian with an effective spin $S = \frac{1}{2}$. The constants of the Zeeman and hyperfine terms are $g_{11} = 1.989\pm0.004$; $g_1 = 1.945\pm0.004$; $A = 3.5 \pm 0.9$ (10^{-4}) cm^{-1}; $B = 23.2\pm0.9$ (10^{-4}) cm^{-1}.

24,290 PARAMAGNETIC-RESONANCE SPECTRA OF THE $3d^5$ CONFIGURATION OF CHROMIUM IN ZnSe AND ZnTe by R.S. Title (IBM Watson Res. Ctr.); Phys. Rev., Vol. 133A, pp. A1613-1616, Mar. 16, 1964

Paramagnetic-resonance measurements have been made for the $3d^5$ configuration

of Cr^+ in ZnSe and ZnTe. The g factor, the cubic crystalline field parameter a, the hyperfine interaction with Cr^{53}, $A(Cr^{53})$, and the hyperfine interaction A_{Zn} with Zn^{67} nuclei occupying any of the twelve equivalent cation sites nearest the chromium have been determined. These resonance parameters are compared with those previoualy measured for Cr^+ in cubic ZnS and CdTe and the variations from crystal to crystal are found to be consistent with changes in the covalency of the bonds and with lattice distortions caused by incorporating Cr^+ substitutionally for the much smaller divalent zinc. The hyperfine interaction with Zn^{67} (or Cd^{111} and Cd^{113}) at second-neighbor sites is, unlike the interaction of the isoelectronic Mn^{++} with these sites, found to vary from crystal to crystal in a manner consistent with changes in the covalent bonding.

24,291 HYPERFINE AND SUPERHYPERFINE STRUCTURE OF MANGANESE IN SnO_2 by W.H. From (Raytheon Res. Lab.), P.B. Dorain (Brandeis U.), and C. Kikuchi (U. Michigan); Bull. Am. Phys. Soc., Vol.9, p.244(A), Mar. 1964

The electron-paramagnetic-resonance spectrum of manganese in a single crystal of SnO_2 was investigated at K- and K_A-band frequencies at a temperature of 77°K. The spin Hamiltonian and the constants for the C-axis and magnetic Z-axis coincident are

$$\mathcal{H} = S\cdot g\cdot H + D[S_Z^2 - 1/3S(S+1)] + E(S_x^2 - S_y^2)$$
$$+ S\cdot A\cdot I + \sum_{i=1}^{2} S_{-Sn}\cdot a_i\cdot I.$$

	x[110] 1.9870	y[110] 1.9870	z[001] 1.9907	Tolerance ±0.0003
g				
A (G)	77.7	75.4	80.64	±0.5
a (G)	30.5	29.5	34.0	±0.5
D (kMc)	26.436			±0.01
E (kMc)	7.91			±0.01

24,292 FORBIDDEN TRANSITIONS IN THE PARAMAGNETIC-RESONANCE SPECTRUM OF Mn^{2+} IN CUBIC MgO^+ by G.J. Wolga and R. Tseng (Cornell U.); Phys. Rev., Vol. 133A, pp. A1563-1567, Mar. 16, 1964

The first order "forbidden" transitions, $M = -\frac{1}{2} \rightarrow +\frac{1}{2}$, $\Delta_m = \pm 1$, in the paramagnetic-resonance spectrum of Mn^{2+} in cubic MgO have been studied both experimentally and theoretically. The analysis was based on a spin Hamiltonian that included the cubic crystal field interaction with the $^6S_{5/2}$ state of Mn^{2+}, magnetic hyperfine interaction with the Mn^{2+} nucleus, and electronic and nuclear Zeeman interactions. Satisfactory agreement between the calculated and observed spectrum was achieved by carrying the hyperfine-perturbation calculation to third order. Analysis of the relative intensity of the forbidden to the allowed transitions permitted an estimate to be made of the trigonal crystal field constant D on the basis of an assumed trigonal distortion to the cubic crystal field. By inserting this value of D into the angular dependent terms in the Hamiltonian, an estimate of the expected linewidths was obtained which agreed well with experiment. The contributions of the estimated trigonal distortion to shifts in the spectrum were too small to be observed for those transitions that are resolved with a powder sample.

24,293 MAGNETIC RESONANCE OF CaF_2 CRYSTALS CONTAINING Fe^{3+} OR Eu^{2+} by F.G. Wakim and A.W. Nolle (U. Texas); Bull. Am. Phys. Soc., Vol. 9, p. 244(A), Mar. 1964

The paramagnetic-resonance spectrum of Fe^{3+} has been observed. Two different samples, one doped in the melt and one by diffusion, gave the same spectrum. The symmetry of the spectrum is trigonal along the body diagonal of the crystal. The spin-Hamiltonian by Bleaney and Trenam has been used. The experimental parameters are g = 1.990, D = -387 G, a = 28 G, and F = -19 G. The spectrum of Eu^{2+} in CaF_2, which has been reported by Ryter, was further investigated. At 3.5°K, the sign of the splitting parameter δ is negative from the intensities in the dispersion spectrum.

24,294 PARAMAGNETIC RESONANCE OF DIVALENT IRON IN CALCIUM OXIDE by A.J. Shuskus (United Aircraft Res. Lab.); J. Chem. Phys., Vol.40, pp. 1602-1604, Mar. 15, 1964

Paramagnetic resonance of divalent iron in single crystals of CaO has been observed at 4.2° and 2°K. The features of the resonance spectrum are: (1) a broad line at $g \simeq 3.30$; (2) a narrow resonance superimposed upon the broad line at $g = 3.298 \pm 0.002$; (3) an asymmetric line at half field with a high-field cutoff at $g \simeq 6.58$. At 4.2°K the double quantum transition exhibits an anisotropic behavior with microwave power and orientation. There is evidence of tetragonal distortions about the Fe^{2+} ion which coincide with the cubic crystal axes. These distortions cannot be ascribed with any degree of certainty to Jahn-Teller splitting.

24,295 PARAMAGNETIC RESONANCE LINE SHAPES OF Fe^{++} IN MgO by D.H. McMahon (Cornell U.); Phys. Rev., Vol. 134A, pp. A128-139, Apr. 6, 1964

The asymmetric ΔM = 2 paramagnetic resonance line shapes of Fe^{++} in MgO are explained using a model of stochastic distributions of cartesian strain components as a strain-broadening mechanism. Strains broaden the ΔM = 2 resonances at lower frequencies by means of a direct zero-field splitting and at higher frequencies by means of a strain-induced change in g value. It is found that this model of broadening gives mathematical expressions for the ΔM = 2 line shapes which agree quantitatively with experimental results.

24,296 SPIN-LATTICE RELAXATION OF THE Fe^{3+} ION IN $K_3(Co,Fe)(CN)_6$ by P.P. Pashinin and A.M. Prokhorov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1990-1991(L), Mar. 1964

Measurement of the spin-lattice relaxation time T_1 at a frequency of 3170 Mc and temperatures between 1.77 and 4.2°K is reported. The results show that the second-order processes still predominate down to T = 1.77°K. Comparison with measurements of the temperature dependence of T_1 at 8750 Mc shows that the first-order processes become important at temperatures below 1.4°K. It is concluded that the spin-lattice relaxation processes are accurately described by Van Vleck's theory.

24,297 ELECTRON SPIN RESONANCE OF $CaWO_4$:Nd^{3+} by V. Ranon (Israel AE Comm.); Phys. Lett., Neth., Vol. 8, pp. 154-155(L), Feb. 1, 1964

An electron spin resonance (ESR) study of Nd^{3+} at 20°K in uncompensated $CaWO_4$ crystals containing about 0.01 per cent Nd^{3+} is discussed. A predominant spectrum corresponding to a tetragonal crystalline field at the sites of the Nd^{3+} ions was observed. A spin Hamiltonian to which one spectrum can be fitted is given. From the parameters of this Hamiltonian, it is concluded that the crystal field does not admix higher J states into the ground state, which can be described by a combination of the eigenfunctions of $\pm J_2$ within the manifold of J = 9/2. Lines of weaker intensity, characteristic of sites of rhombic symmetry, were also observed.

24,298 ELECTRON PARAMAGNETIC RESONANCE OF Gd^{3+} IN CaF_2 by V. M. Vinokurov, M.M. Zaripov, Yu.E. Pol'skii, V.G. Stepanov, G.K. Chirkin and L. Ya. Shekun (Ul'yanov-Lenin Kazan State U.); Soviet Phys.-Solid State, Vol. 5, pp. 2126-2129, Apr. 1964

The electron paramagnetic resonance spectra of tegragonal and trigonal Gd^{3+} complexes in the CaF_2 crystal lattice in the case of H ∥ Z have been investigated. The b_4^4 constants for the tetragonal complex and the b_4^3 and b_6^3 constants for the trigonal complex are found, and the absolute sign of the spin-Hamiltonian constants is determined from measurements at low temperatures.

24,299 PARAMAGNETIC RESONANCE OF GADOLINIUM IN DYSPROSIUM ETHYL SULFATE by J.A. Dweck and G. Seidel (Brown U.); Bull. Am. Phys. Soc., Vol.9, p. 243(A), Mar. 1964

The paramagnetic-resonance spectrum of gadolinium (0.1%) has been observed at 35 kMc in the concentrated paramagnetic salt dysprosium ethyl sulfate, at temperatures from 0.4° to 2°K, using a ^{3}He cryostat. The dysprosium ions have $g \approx 10.8$ and are essentially all aligned at low temperatures. The spin Hamiltonian is found to be somewhat different from that of gadolinium in the diamagnetic lanthanum ethyl sulfate. The shift of the $M_S = -1/2$ to $+1/2$ transition in the DyES as compared to the LaES is consistent with the calculated dipolar fields of the dysprosium ions. Below 1°K, the dysprosium resonance was also observed. For the spherical sample used, this resonance was found to split into approximately 20 maxima, which result from higher-order magnetostatic modes.

24,300 A NEW USE OF THE KRONIG-KRAMERS RELATIONS IN NUCLEAR MAGNETIC RESONANCE by H.C. Bolton, G.J. Troup and G.V.H. Wilson (Monash U., Australia); Phil. Mag., Vol. 9, pp. 591-605, Apr. 1964

Many weak or readily saturable nuclear magnetic resonances can be detected only by the use of the dispersion mode in a nuclear induction system, and dispersion records of complicated or partially resolved spectra may be difficult to interpret. However, it is shown that, for systems obeying Bloch or Redfield equations, the Kronig-Kramers (K-K) relations may justifiably be used to transform a dispersion record taken in the presence of saturation, under slow modulation conditions, into the more readily interpretable absorption record. The K-K relations are shown to apply to the derivatives of the absorption and dispersion line shapes, which are the quantities usually recorded, and to transform a modulation-broadened dispersion curve into the appropriate modulation-broadened absorption curve. The relations hold for derivatives of any order and may, therefore, be applied to records from an apparatus employing phase-sensitive detection at any harmonic of the modulation frequency. Results are presented for some analytical cases, and details of the computational method are given. Simple trapezoidal integration is found to yield high accuracy. The resonance of ^{9}Be in beryl is used to confirm the applicability of the K-K relations in the presence of saturation.

24,301 EFFECT OF AN EXTERNAL ELECTRIC FIELD ON NUCLEAR RESONANCE by A.M. Vasil'ev; Soviet Phys.-Solid State, Vol. 5, pp. 1042-1050, Nov. 1963

It is shown that an external electric field may affect the nuclear resonance frequency of ions $^{23}Na^{+}$ in an ionic crystal. The electric field polarizes the electron shells of the ions making up the crystal. The constant quadrupole bond changes in the second approximation of the perturbation theory, which produces a change in the frequency. The conditions are discussed under which the effect may be linear with the field, and a variational method is used to determine the quantitative value of the effect.

24,302 NUCLEAR MAGNETIC RESONANCE IN α- AND β-MANGANESE METALS by Y. Masuda, K. Asayama, S. Kobayashi and J. Itoh (Osaka U.); J. Phys. Soc. Japan, Vol. 19, pp. 460-468, Apr. 1964

Nuclear magnetic resonance studies on Mn^{55} in α- and β-Mn metals have been made by both steady and pulse methods. Nuclear spin-lattice relaxation time T_1 and spin-spin relaxation time T_2 were measured by the pulse method in the temperature range of 1.5°K to 77°K. The measured value of T_1T of β-Mn has a constant value of 7 mm sec°K through the temperature range measured. Using both the T_1T value and the Knight shift, the origin of the effective magnetic field acting on a nucleus in a Mn metal was determined. T_2 of 0.1 msec was observed to be temperature independent. Several nuclear spin-lattice relaxation mechanisms together with the origin of the effective magnetic field in the Mn metal are discussed. T_1 due to the dipole, quadrupole, and orbital interactions is calculated using free electron approximation in which the electronic wave function includes partly p- or d-character. It is shown that the orbital interaction is more effective than those due to the dipole or quadrupole interaction. Mn^{55} nuclear magnetic resonance in an antiferromagnetic α-Mn metal was observed by the pulse method in zero external magnetic field and at temperatures of 1.5°K to 4.2°K.

24,303 NUCLEAR MAGNETIC RESONANCE IN SOLID He^3 - THE EXCHANGE BATH by R.L. Garwin (IBM Watson Res. Lab.) and A. Landesman (Cent. Etude Nuc., Saclay, France); Phys. Rev., Vol. 133A, pp.A1503-1514, Mar. 16, 1964

Spin-echo experiments were made on β-phase He^3 and the exchange interaction J between He^3 atoms were measured in a consistent way, both by the 'exchange narrowing' of the line (exchange lenghthening of T_2) and by the strong reduction of T_1 at low magnetic fields ($\gamma H_0 \approx J$). J is found to increase very rapidly with increasing molar volume, ranging from less than 20 kc/sec at a lattice constant of 3.4 A to 90 kc/sec at 3.5 A, and to about 300 kc/sec at 3.6 A. These exchange interactions are much too small to account for the "departure from the Curie law" found by Adams, Meyer, and Fairbank. It is shown that the susceptibility is, in fact, "Curie law" (in their temperature range) and that they were reporting - as a susceptibility anomaly - the effect of a long exchange bath-lattice relaxation time (observed for the first time in the present experiment). This exchange-lattice relaxation time varies as $T^{-n}(7 < n < 11)$ and is ≈ 100 sec at 1°K for β-phase He^3 of 3.5 A lattice constant. The results for the exchange-lattice relaxation time are compared with a modification of a theory by Griffiths. A major mystery remains - the exchange-bath heat capacity as measured by the spin-echo method exceeds the calculated value by $> 10^3$. The exchange interaction is discussed and compared with the prediction of Saunders and others.

24,304 NMR IN $PuAl_2$ by D.O. Van Ostenburg, D.J. Lam, M.B. Brodsky and H.D. Trapp (Argonne Lab.); Bull. Am. Phys. Soc., Vol.9, p. 261(A), Mar. 1964

The intermetallic compound $PuAl_2$ has the Cu_2Mg-type structure and is isostructural with UAl_2. The $^{27}Al(I = 5/2)$ resonance has been observed and consists of a central line and four satellites. The width of the central line is due to the second-order quadrupolar, the anisotropic Knight shift, and the dipole-dipole interactions. The quadrupolar coupling constant e^2qQ/h obtained from the satellite separation and the second-order splitting is in the vicinity of 3.88 Mc. The Knight shift is field-dependent and is (0.133±0.006) per cent at an external field of 14.0 koe.

24,305 THEORETICAL LINE SHAPES ASSOCIATED WITH ANISOTROPIC KNIGHT SHIFTS AND QUADRUPOLE INTERACTIONS IN POLYCRYSTALLINE SAMPLES by D.G. Hughes (U. Hull, England) and T.J. Rowland (U. Illinois); Canadian J. Phys., Vol. 42, pp. 209-213(L), Jan. 1964

Numerical calculations of line shapes due to anisotropic Knight shifts and quadrupolar interactions in polycrystalline samples are presented. These computer calculations are based on the following assumptions: (1) axial symmetry (2) small anisotropy and (3) symmetric broadening as represented by a Gaussian function whose width is independent of angular orientation.

24,306 NUCLEAR MAGNETIC RELAXATION OF THREE SPIN SYSTEMS UNDERGOING HINDERED ROTATIONS by R.L. Hilt and P.S. Hubbard (U. North Carolina); Phys. Rev., Vol. 134A, pp. A392-398, Apr. 20, 1964

The longitudinal nuclear magnetic relaxation of an ensemble of spin systems exposed to a constant magnetic field H_0k is calculated. Each spin system consists of three identical spin-1/2 nuclei located at the vertices of an equilateral triangle. Each spin system undergoes hindered rotation about an axis that is perpendicular to the plane of the three spins, and is oriented at an angle β with the constant field. Two models are studied: In one model there are only three possible equilibrium orientations of each system about its rotation axis and the group makes random jumps between these orientations; in the other model each group performs stochastic rotational diffusion about its rotation axis. Both models lead to results of the same form, which differ only in the definition of the correlation time τ_c of the motion. It is assumed that the relaxation is due to the magnetic dipole-dipole interactions between the nuclei within each group. The relaxation is, in general, the sum of four decaying exponentials. For $\beta=0$, the relaxation does not decay to zero. Explicit solutions have been calculated for $\cos\beta = 0, \pm 0.1, \pm 0.2, \cdots, \pm 1.0$ for many values of the correlation time. Explicit solutions have also been calculated for situations in which the axes of hindered rotation are isotropically oriented. All results are compared with the results of a calculation in which cross correlations are omitted, and are shown to differ significantly.

24,307 CALCULATION OF THE SECOND MOMENT OF A NUCLEAR MAGNETIC RESONANCE LINE IN ISOTROPIC ROTATION OF MOLECULES by L. V. Dmitrieva and V.V. Moskalev (Leningrad State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1623-1624, Feb. 1964

Accurate formulas for calculating the second moment of the nuclear magnetic resonance line are derived. The rotation of urotropine molecules in the solid phase is found. The value of the potential barrier hindering the orientations is found to be 22 kcal/mole which compares with Smith's value 18 kcal/mole.

24,308 NUCLEAR SPIN RELAXATION IN TRANSITION METALS; CORE POLARIZATION by Y. Yafet and V. Jaccarino (Bell Labs.); Phys. Rev., Vol. 133A, pp. A1630-1639, Mar. 16, 1964

The nuclear relaxation induced by core polarization (c.p) in a transition metal is calculated in the tight-binding limit. It is shown that a Korringa-like relation exists between the c.p Knight shift and the c.p relaxation rate, but with a factor that inhibits relaxation, the numerical value of which depends on the relative weight of Γ_5 and Γ_3 orbitals at the Fermi surface. Using estimates of the hyperfine fields, the relaxation rates associated with the contact c.p., and orbital interactions are calculated for three transition metals. It is found that all three processes make significant contributions. The agreement with the measured relaxation rates is satisfactory considering the uncertainties in the estimated numbers.

24,309 LONGITUDINAL NUCLEAR SPIN-SPIN RELAXATION by R.L. Strombotne and E.L. Hahn (U. California, Berkeley); Phys. Rev., Vol. 133A, pp. A1616-1629, Mar. 16, 1964

A theoretical and experimental study is made of the nuclear magnetization which appears after a sudden unidirectional step magnetic field is applied nonadiabatically to an ordered spin system which has been prepared by the process of adiabatic demagnetization. The magnetization exhibits damped oscillations about a nonvanishing equilibrium value. The oscillation frequencies correspond to the fundamental and harmonic components of Larmor frequency determined by the combined effect of local dipole and external step fields. The oscillations arise as the internally ordered dipole-dipole interaction energy exchanges with the suddenly imposed Zeeman energy reservoir. A density matrix calculation carried to second order in time-dependent perturbation theory, combined with a Gaussian decay model, accounts for the observed oscillations within times comparable to the decay time. Fluorine nuclei in single CaF_2 crystals are studied for various crystal orientations with respect to the applied step field. For long times after step field application the attainment of thermal equilibrium between dipole-dipole and Zeeman reservoirs permits prediction, using the spin temperature concept, of magnetization developed along the step field.

24,310 NUCLEAR SPIN-LATTICE RELAXATION IN THREE-SPIN MOLECULES by L.K. Runnels (Louisiana State U.); Phys. Rev., Vol. 134A, pp. A28-36, Apr. 6, 1964

The free longitudinal relaxation of the nuclear magnetization of systems of three identical spins 1/2 at the corners of an equilateral triangle is investigated using the semiclassical form of the density operator theory. The relaxation mechanism investigated is a fluctuating dipolar interaction between the spins. Assuming only that the symmetry of the thermal motion of the molecules preserves the complete equivalence of the three spins, the general relaxation equation is obtained before adopting models for this thermal motion. The effect of correlations between different pairwise interactions is studied; this effect can be more significant in the case of anisotropic reorientations possible in solids than for isotropic motion. For systems initially describable by a spin temperature, the effect of cross correlations always is to retard the relaxation. In general the relaxation is described by a sum of four exponentials, although three suffice for isotropic motion and two for the limit of long correlation times. An "effective relaxation time" is defined, the calculation of which is far simpler than that of the complete solution.

24,311 NUCLEAR MAGNETIC RELAXATION IN Sc AND La METALS by Y. Masuda (Kobe U.); J. Phys. Soc. Japan, Vol. 19, p. 238(L), Feb. 1964

The nuclear magnetic spin-lattice relaxation time (T_1) and the spin-spin relaxation time (T_2) of Sc^{45} and La^{193} have been measured between 1.5 to 77°K. T_1 of both metals is proportional to (1/T). The major part of relaxation is of orbital origin. The superconducting state should have almost the same Knight shift as the normal state on the assumption that the magnitude of orbital paramagnetism is the same in both states.

24,312 KNIGHT SHIFTS AND LINEWIDTHS FOR In AND Te NMR IN METALLIC InTe by K.C. Brog, W.H. Jones, Jr., and F.J. Milford (Battelle); Bull. Am. Phys. Soc., Vol. 9, p. 261(A), Mar. 1964

Both the ^{115}In and the ^{125}Te nuclear resonances have been observed in the cubic, metallic state of InTe. Indium has a paramagnetic Knight shift of 2.8 per cent and a linewidth of 65 G. The corresponding values for tellurium are 0.26 per cent and 24 G. These results are independent of the applied magnetic field. The InTe is diamagnetic with a susceptibility of -0.17×10^{-6} emu/g. The observed linewidths are at least an order of magnitude larger than the dipolar widths calculated from the Van Vleck second-moment formula. If quadrupole broadening of the ^{115}In resonance due to imperfections can be ignored, the observed widths may be accounted for by indirect exchange interactions and/or pseudodipolar effects. In any case, these interactions are thought to be the chief source of linewidth in the ^{125}Te resonance where the spin of 1/2 precludes any quadrupole effects. By calculating second moments with lattice sums over both like and unlike nearest neighbors, some estimate of the interaction constants can be made. Preliminary estimates indicate that the In linewidth is due mainly to the In-In pseudodipolar interaction, while the Te linewidth arises from both pseudodipolar and indirect-exchange interactions with In nuclei.

DIAMAGNETISM

24,313 QUESTION OF SIZE CORRECTIONS TO THE STEADY DIAMAGNETIC SUSCEPTIBILITY OF SMALL SYSTEMS by L. Friedman (U. Pittsburgh); Phys. Rev., Vol. 134A, pp. A336-344, Apr. 20, 1964

The order of magnitude of the (orbital) diamagnetic susceptibility of a free-electron gas is investigated for the case of "small" systems. A small system is, by definition, one whose characteristic linear dimensions are very much less than the radii of the average classical electronic orbits in an applied dc magnetic field. For the case of plane-slab geometry, exactly the Landau susceptibility (i.e., no size effect) is obtained for Maxwell-Boltzmann statistics. Furthermore, on the basis of the latter calculation, it is explicitly demonstrated that the use of the WKB approximation leads to a spurious size effect, suggesting that this (or equivalent) approximations may be responsible for size corrections found by other authors. For the degenerate case, the Landau result is also obtained, to within a numerical factor. Finally, no size correction is obtained in the small size limit for an electron gas confined by a harmonic potential well; this further suggests that the Landau result is independent of the choice of boundary potential.

Diamagnetic Susceptibility of Diamond, Si, Ge and Sn - See 24,258

24,314 INVESTIGATION OF THE DE HAAS-VAN ALPHEN EFFECT IN BISMUTH AT ULTRA-LOW TEMPERATURES by N.B. Brandt, T.F. Dolgolenko and N.N. Stupochenko (Moscow State U.); Soviet Phys.-JETP, Vol. 18, pp. 908-918, Apr. 1964

Quantum oscillations of the magnetic susceptibility of bismuth in a magnetic field at temperatures between 0.08 and 0.12°K have been investigated. The shape of the Fermi surface is examined on the basis of the results obtained. It is shown that the shape of the hole part of the Fermi surface is close to an ellipsoid of revolution, and the form of the electronic part of the Fermi surface agrees with the Jones-Shoenberg model.

24,315 DE HAAS-VAN ALPHEN EFFECT AND FERMI SURFACE IN RHENIUM by A.J. Joseph and A.C. Thorsen (Atomics Intl.); Phys. Rev., Vol. 133A, pp. A1546-1552, Mar. 16, 1964

The de Haas-van Alphen effect in rhenium has been studied by a null-deflection torsion balance technique in magnetic fields up to 40 kg. It is shown that a set of ellipsoids and a set of dumbbell-like Fermi surface segments located on the A-L symmetry line of the reduced Brilluoin zone can account for most of the observed data. de Haas-van Alphen oscillations associated with magnetic breakdown phenomena provide evidence in support of the above model. This model furthermore requires that there be a degeneracy in the energy spectrum along the A-L line, as predicted by group theory.

24,316 DE HAAS-VAN ALPHEN EFFECT OF GALLIUM by J.H. Condon (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 239(A), Mar. 1964

Torque-method measurements of the dKvA effect using magnetic fields to 31 kg in the three principal planes and two other planes of a single crystal of high-purity gallium have been completed. The results agree well with those of Shoenberg wherever comparable. Three new closed Fermi-surface pieces and other dHvA periods traceable over limited magnetic-field directions are shown to exist with dimensions from one-thousandth to one-half the zone size. The data appear inexplicable by the nearly-free-electron model.

24,317 DE HAAS-VAN ALPHEN EFFECTS IN HIGH DC MAGNETIC FIELDS by A. Goldstein and S. Foner (Natl. Magnet Lab., MIT); Bull. Am. Phys. Soc., Vol. 9, p. 239(A), Mar. 1964

dHvA effects in W, Zn, Cr, and Ga have been examined with a first-derivative, rather than a second-derivative, dc field-modulation technique. The method, extended to 90 kg and to 1.2°K, demonstrates that accurate-period and effective-mass data can be measured. Near the c axis in gallium, preliminary measurements yield the periods (in units of 10^{-7} G^{-1}) 44, 12, and 1.2. Near the a axis, a short period of about 4×10^{-8} was obtained. The results near the c direction for the two short oscillations agree closely with prior independent ultrasonic data of Shapira. Detailed period and effective-mass data versus orientation are presented for gallium. Some relevant advantages of the modulation technique are discussed briefly.

24,318 DE HAAS-VAN ALPHEN EFFECT IN ZINC AND Zn-Cu ALLOYS by R.J. Higgins, J.A. Marcus and D.H. Whitmore (Northwestern U.); Bull. Am. Phys. Soc., Vol. 9, p. 240(A), Mar. 1964

Torsion-balance measurements of de Haas-van Alphen oscillations have now been extended up to 33 kg, allowing the observation of period changes in the higher-frequenay oscillations in zinc-0.2 at.% copper. In addition, several high-frequency oscillations not previously reported have been observed above 28 kg in a very pure crystal of zinc

Torsion axis	[0001]	$[11\bar{2}0]$	$[11\bar{2}0]$
Field direction	$[11\bar{2}0]$	$[10\bar{1}0]$	[0001]
Frequency (10^6 G)	27	74	17 and 12

where directions are given in real space.

24,319 DE HAAS-VAN ALPHEN EFFECT IN Tl by M.G. Priestley (U. Chicago); Bull. Am. Phys. Soc., Vol.9, p. 239(A), Mar. 1964

A study of the de Haas-van Alphen effect in Tl by the pulsed-field method was reported. The angular variation of period has been measured in the $(10\bar{1}0)$ and (0001) planes for samples with $R_{300°}/R_{4.2°} \approx 3000$. In general, the data agree with the nearly-free-electron model for zones 3 and 4 in the single-zone scheme implying that magnetic breakdown is not complete over the hexagonal face of the Brillouin zone.

de Haas-van Alphen Effect in Ca - See 23,852

OPTICAL PROPERTIES

GENERAL

24,320 THE THEORY OF DIRECT TRANSITIONS IN SEMICONDUCTORS by R.H. Pantell, M. DiDomenico, Jr. and O. Svelto (Bell Labs.); Bell Sys. Tech. J., Vol. 43, pp. 805-816, Mar. 1964

The problem of direct interband transitions in semiconducting crystals is considered in detail. The solution of the problem is shown to lead to a system of simultaneous coupled nonlinear differential equations. These equations do not distinguish between static and dynamic fields, and are obtained without recourse to any approximation procedures. They therefore apply for electromagnetic fields of arbitrary amplitude. It is shown, finally, that the linearization of these equations correctly predicts the fundamental optical absorption edge and the photoconductive rate equations which result in photomixing phenomena.

24,321 THEORY OF HEAVILY DOPED SEMICONDUCTORS. INTERBAND TRANSITIONS by V.L. Bonch-Bruevich and R. Rozman (Lomonosov Moscow State U.); Soviet Phys.-Solid State, Vol. 5, pp. 2117-2125, Apr. 1964

The problem of determining the density of states from optical data relating to interband transitions in a heavily doped semiconductor is considered. The absorption and emission coefficients of light are derived taking account of the peculiarities of the energy spectrum. It is shown that in some cases the frequency dependence of the absorption coefficient makes it possible to determine correctly the density of states in the region of the "tail". The theory can also be used for the interpretation of X-ray data in solids.

24,322 ULTRAVIOLET OPTICAL PROPERTIES OF DIAMOND by W.C. Walker and J. Osantowski (U. California, Santa Barbara); Phys. Rev., Vol. 134A,

pp. A153-157, Apr. 6, 1964

The absolute reflection spectrum of type IIa diamond has been measured at room temperature from 4 to 30 ev and analyzed by dispersion techniques to obtain the optical parameters. Structure observed in the dielectric constant near 7, 12, 16, 20, and 24 ev was attributed to interband transitions at critical points in the joint density-of-states function. The new high-energy structure near 16, 20, and 24 ev was assigned to transitions near the L point of the Brillouin zone. Experimental interband transition energies are compared to band theory calculations.

24,323 OPTICAL AND ELECTRICAL PROPERTIES AND ENERGY BAND STRUCTURE OF ZnSb by H. Komiya, K. Masumoto and H.Y. Fan (Purdue U.); Phys. Rev., Vol. 133A, pp. A1679-1684, Mar. 16, 1964

Single crystals of p-type ZnSb have been grown by pulling from the melt. The carrier concentration is of the order of 10^{16} cm^{-3}. The Hall mobility is of the order of a few hundred $cm^2/sec-v$ at room temperature, and is highest for current along the c axis and lowest for current along the b axis. Indirect and direct transitions have been observed in the absorption edge. The indirect transitions begin at the photon energy: 0.50 ev at 300°K, 0.59 ev at 77°K, and 0.61 ev at 4.2°K, independent of polarization. The direct transitions appear to begin at the lowest photon energy for $E \| c$ and at the highest photon energy for $E \| a$. The carrier absorption of long wavelengths is highest for $E \| c$. The results indicate that the valence band has three closely spaced bands near the maximum which corresponds to either the point Γ or the points R of the Brillouin zone, while the minimum of the conduction band is at the other position. The effective mass tensor of holes is estimated.

ABSORPTION (TRANSMISSION)

24,324 THEORY OF OPTICAL TRANSITIONS IN LOCAL CENTERS by L.S. Kukushkin (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1581-1585, Feb. 1964

A method for analyzing the form and the temperature dependence of the light absorption band due to local centers in semiconductors is proposed. It consists of setting up an integral equation which corresponds to the form of the band, and analyzing its solutions. The possibility of deriving the characteristics of the centers from the experimentally determined form of the absorption band at $T = 0$ is discussed. The results may be used to describe the absorption bands of slow neutrons in crystals or the form of Mössbauer's wings.

24,325 ON DETERMINATION OF ABSORPTION AND REFLECTION COEFFICIENTS by A. Kahan (AF Cambridge Res. Labs.); Appl. Optics, Vol. 3, pp. 314-315(L), Feb. 1964

An analytical procedure for calculating bulk reflection and absorption coefficients from experimentally determined reflection and transmission coefficients is presented. The method is a closed solution of an equation presented earlier by Nazarewicz et al., who solved it numerically. The two formulas presented for the reflection and absorption coefficients permit direct substitution of the experimental values and straightforward calculation of the required coefficients.

24,326 ANISOTROPIC ABSORPTION OF LIGHT BY CURRENT CARRIERS IN SEMICONDUCTORS IN A STRONG MAGNETIC FIELD by V.A. Yakovlev (Volgograd Pedagogical Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 942-944, Nov. 1963

The coefficients for absorption of light by conduction electrons are calculated for the case of the presence of a strong magnetic field and for various directions of the light relative to the field. The absorption of the resonance frequency of light ω_0 vanishes when $\omega_0 \to 0$; for relatively small fields ($\hbar\omega_0 \ll kT$), it is proportional to the square of the electric field strength, and for $\hbar\omega_0 \gg kT$, it depends linearly on the field.

24,327 THE ABSORPTION SPECTRUM OF TIN DOPED GERMANIUM by S. Munesue and T. Arai (Elect. Commun. Lab.); Phys. Lett., Neth., Vol. 8, pp. 162-164(L), Feb. 1, 1964

The optical absorption spectrum of tin-doped germanium is discussed. The absorption curves shift to longer wavelengths and to higher absolute values as the tin concentration increases. The experimental data suggest that the energy gap changes in tin-doped germanium are produced by electron-electron interactions and other effects. Constant absorption was observed at the lower photon energies. The intensity of this absorption depends on the tin concentration; its origin has not yet been determined.

24,328 QUANTUM ABSORPTION IN ALUMINUM AND INDIUM by I.N. Shklyarevskii and R.G. Yarovaya; Optics and Spectroscopy, Vol. 16, pp. 45-48, Jan. 1964

Optical constants in the 0.4-2 μ region were measured for layers of aluminum and indium which were obtained by vacuum evaporation. Values found for the index of refraction and absorption coefficient of aluminum were corrected for surface oxidation in accordance with results obtained earlier. It was discovered that both metals in this spectral region have quantum absorption bands which are associated with interband transitions of conduction electrons. For aluminum this absorption can be separated from the intraband absorption. The long-wavelength edge of the quantum absorption was determined, and the frequency dependence of the absorption coefficient close to this edge was investigated. The results obtained were compared with calculations of the energy bands of aluminum.

24,329 TRANSMITTANCE OF DOPED SILICON BETWEEN 40 AND 100 μm by S. Walles and S. Boija (Inst. Optical Res., Sweden); J. Optical Soc. Am., Vol. 54, p. 133(L), Jan. 1964

Investigations have been made on the transmittance of doped silicon between 40 and 100 μm using an infrared spectrometer. This special spectrometer is described. The reflectance and the absorption coefficient are given as functions of wavelength. The absorption coefficient increases from 13 to 20 cm^{-1} as the wavelength increases from 40 to 100 μm.

24,330 INFRARED LATTICE-VIBRATION TRANSMISSION SPECTRUM OF GaAs by S. Iwasa, I. Balslev and E. Burstein (U. Pennsylvania); Bull. Am. Phys. Soc., Vol. 9, p. 237(A), Mar. 1964

Room-temperature transmission measurements have been performed in the region of the fundamental optical-absorption frequency on (a) ground and polished single crystals of thicknesses ranging from 1 to 100 μ supported on high-purity silicon plates and (b) epitaxial films below 1μ in thickness deposited on germanium. The data do not exhibit the fine structure reported by W. Cochran et al. in the frequency range 260 to 300 cm^{-1}. In addition, the peak absorption coefficient at 268 cm^{-1}, the fundamental transverse optical-vibration frequency ω_T, was found to be at least an order of magnitude greater than was reported by Cochran and coworkers. By carrying out measurements at oblique incidence, an additional transmission minimum was found at 290 cm^{-1} that corresponds to the fundamental longitudinal optical vibration frequency ω_L. The ratio $(\omega_L/\omega_T)^2 = 1.17$ is in good agreement with the (liquid-helium temperature) value of 1.18 obtained by Hass and Henvis from an analysis of the reflection spectrum.

24,331 OPTICAL PROPERTIES OF $InAs_ySb_{1-y}$ LAYERS PREPARED BY THERMAL EVAPORATION by R. Potter and G. Kretschmar (U.S. Naval Ord. Lab.); Infrared Phys., Vol. 4, pp. 57-65, Mar. 1964

By extending a technique developed for InSb the system $InAs_ySb_{1-y}$ has been produced over the range $0 \leq y \leq 1$ by the thermal evaporation of the metallic constituents. The films, as produced, were "n" type in character with carrier concentration in excess of 10^{18} cm^{-3}. Because of the small effective masses of these compounds, dispersion effects were apparent for the refractive indices. Transmission measurements for the region from 1 to 6 μ are shown. On the basis of the Kane model for the InSb conduction band an estimate is given for (m_o^*/m_e) at the conduction band minimum as a function of y.

24,332 OPTICAL DOUBLE-PHOTON ABSORPTION IN CdS by R. Braunstein and N. Ockman (RCA Labs.); Phys. Rev., Vol. 134A, pp. A499-507, Apr. 20, 1964

Observations have been made of the two-photon excitation of an electron from the valence to the conduction band in CdS ($E_g = 2.5$ ev) using a pulsed ruby laser ($\hbar\omega = 1.78$ ev). The radiative recombination emission from exciton and impurity levels subsequent to the simultaneous absorption of two quanta of $\hbar\omega = 1.78$ ev was observed as a function of laser intensity and compared to the emission excited by single-quanta absorption for photons of $\hbar\omega > E_g$. It was found that the intensity of the recombination radiation is proportional to I_0^n for single-quanta excitation and I_0^{2n} for double-quanta excitation, where I_0 is the excitation intensity and n is a constant which differs for different groups of emission lines. The observed cross section for double-quanta excitation is compared with theory utilizing the band parameters of CdS.

24,333 EXCITON STRUCTURE IN A CADMIUM SELENIDE CRYSTAL by V.V. Sobolev; Optics and Spectroscopy, Vol. 16, pp. 40-45, Jan. 1964

Absorption spectra have been studied in the region of the long-wavelength fundamental absorption edge in CdSe. An exciton interpretation and classification of the linear structure of the absorption spectra is proposed.

24,334 OPTICAL ABSORPTION IN HgTe AND HgCdTe by M.D. Blue (Honeywell Res. Ctr.); Phys. Rev., Vol. 134A, pp. A226-234, Apr. 6, 1964

Absorption and reflectivity near the fundamental absorption edge have been measured in the HgTe-CdTe alloy series for CdTe concentrations of up to 28 per cent. In the HgTe rich region, the edge shifts to longer wavelengths and decreasing temperature. For HgTe, the absorption rises to 2×10^4 cm^{-1} at $\hbar\omega = 0.6$ ev. Absorption did not decrease below 1.4×10^3 cm^{-1} at room temperdture. The theory of optical absorption in zincblende compounds is reviewed. Absorp-

tion in this alloy series agrees with theory for direct transitions with an energy-independent matrix element evaluated by Kane for InSb. Analysis of reflectivity in HgTe indicates an electron effective mass of 0.02m at 100°C.

24,335 ABSORPTION SPECTRUM OF THE Mn^{2+} ION IN ZnS MONOCRYSTALS by A.I. Ryskin, G.I. Khilko, B.I. Maksakov, and K.K. Dubenskii; Optics and Spectroscopy, Vol. 16, pp. 149-151, Feb. 1964

The absorption spectrum of the Mn^{2+} ion in ZnS monocrystals has been measured. The spectrum was found to consist of a band system. Individual bands correspond to transitions of the Mn^{2+} ion in a crystal field ob cubic symmetry. A considerable shift of the bands relative to the position predicted by crystal field theory is attributed to the partially covalent nature of the bonds in ZnS.

24,336 THE 2100A BANDS OF CS_2 by A.E. Douglas and I. Zanon (Natl. Res. Council, Ottawa); Canadian J. Phys., Vol. 42, pp. 627-631, Apr. 1964

The CS_2 bands which lie near 2100A have been photographed in absorption with a high-dispersion spectrograph and a partial analysis has been made of the band system. Though a number of features remain unexplained, strong evidence has been obtained that in the upper state (a $^1B_2$ state) the molecule is nonlinear with an S-C-S bond angle of 153° and a C-S bond distance of 1.66A.

24,337 ABSORPTION AND FLUORESCENCE SPECTRA OF Eu^{2+} IN ALKALI HALIDE CRYSTALS by R. Reisfeld and A. Glasner (Hebrew U., Jerusalem); J. Optical Soc. Am., Vol. 54, pp. 331-333, Mar. 1964

Alkali halide crystals and pressed disks doped with divalent europium were prepared and their absorption and fluorescence spectra measured. There are two broad absorption bands in the ultraviolet, peaking at ~250 and 330 mμ, both due to the transition $4f^7 \rightarrow 4f^6 5d^1$, and attributed, after comparison with the absorption spectra of Eu^{2+} observed by previous workers in various other media, to the splitting of the 5d orbitals by the crystal field. In addition to the many sharp bands riding on the main absorption bands, one peaking at 270 mμ has been observed, in complete analogy with the Gd^{3+} spectrum. The fluorescence emission spectra are identical, irrespective of the wavelength of irradiation (250 to 300 mμ).

24,338 OPTICAL ABSORPTION AND LUMINESCENCE ASSOCIATED WITH IODIDE CENTERS IN AgCl by F. Moser (Eastman Kodak); Bull. Am. Phys. Soc., Vol. 9, p. 228(A), Mar. 1964

Silver chloride crystals containing 10^{16}-10^{19} iodide ions per cm^3 have been grown from the melt. The iodide produces an absorption band, at N_2 temperature, with a peak at 3.13 ev and a half-width of about 0.15 ev (the AgCl edge is near 3.30 ev). This band is narrow, approximately Gaussian, and its intensity is proportional to the iodide concentration, suggesting that the band is due to localized electron transitions at isolated iodide centers. Excitation at low temperature in the iodide band, or in the AgCl lattice, gives an emission with a peak near 2.60 ev and a half-width of about 0.20 ev. With increasing temperature, this emission band shifts to longer wavelengths, broadens, and is thermally quenched near 200°K. The green emission seen in pure crystals, which quenches near 130°K, cannot be excited in these crystals. The iodide ion apparently introduces a level near the valence band (shallow-hole trap) that shifts about 0.5 ev when an electron is removed (or a hole trapped). Radiative recombination at this iodide center is much more probable than recombination at the center responsible for the intrinsic green emission.

24,339 PECULIARITIES OF THE ABSORPTION SPECTRUM OF MANGANESE FLUORIDE CRYSTALS by V.V. Eremenko and A.I. Belyaeva (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 2106-2112, Apr. 1964

The absorption spectrum of manganese fluoride crystals has been investigated in the temperature range 20-290°K. It is shown that the splitting of the band due to the transition $^6S_{5/2} \rightarrow {}^4G_{3/2}$ results from deviations of the local crystal field symmetry from cubic. The shape of the absorption bands is analyzed. The result of the analysis contradicts the hypothesis that the sharply polarized satellite $\nu = 25249\ cm^{-1}$ of the 25303.7 cm^{-1} band owes its appearance to exciton effects.

24,340 ABSORPTION SPECTRUM OF SODIUM NITRITE CRYSTALS AT 20°K by Yu.A. Kulyupin and A.F. Yatsenko (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 2017-2023, Apr. 1964

The absorption spectrum of $NaNO_2$ in the region 3000 to 4000 A has been investigated with polarized light at 20°K. It is observed that the spectra, consisting of a series of narrow equidistant lines, are different for the three crystallographic directions. The experimental data show that the symmetry of the NO_2^- ion deviates slightly from C_{2v} towards C_2; the pure electronic transition, which is forbidden along the c axis, becomes allowed, when combined with vibrations of a lattice of appropriate symmetry. The effect of deformations on the spectrum is discussed. As the deformation increases, the spectrum shifts towards red and the lines become broader.

24,341 MULTIPHONON PROCESSES IN $SrTiO_3$ by G. Rupprecht (Tyco Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 216(A), Mar. 1964

The transmittance of single-crystal strontium titanate has been measured in the wavelength range 4-12 μ on a series of samples of different thickness. The absorption throughout this region consists of a continuous background on which is superposed a number of peaks. The absorption index k for the continuous absorption varies with frequency as $k = k_0 \exp(-\omega/\omega_0)$ over 4 orders of magnitude, with $k_0 = 17$ and $\omega_0 = 153\ cm^{-1}$. From classical dispersion theory, one expects k to be proportional to ω^{-3}, which is very different from the observed behavior. An explanation was given in terms of a multiphonon process and a coupling of acoustic and optical phonons.

24,342 ABSORPTION R LINES IN RUBY by T.V. Gvaladze, V.K. Konyukhov, A.M. Prokhorov, V.Ya. Khaimov-Malkov and G.P. Shipulo (Acad. Sci. USSR); Optics and Spectroscopy, Vol. 16, pp. 31-33, Jan. 1964

Absorption R lines in ruby (0.04% Cr_2O_3 by weight) were studied at 16°, 60°, and 95°C. The intensity of R_1 and R_2 lines was shown to be independent of temperature and free from reabsorption in the temperature range. The luminescent de-excitation times of the R_1 and R_2 lines were calculated from the experimental data.

24,343 LIGHT ABSORPTION BY FREE CARRIERS IN SEMICONDUCTORS WHOSE IMPURITY CENTERS HAVE A SHORT-RANGE FIELD by V.A. Yakovlev (Volgograd Pedagog. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1555-1557, Feb. 1964

The wave function for a band electron in a field of impurities having a small radius of action is derived. Calculations are made for the coefficients of light absorption by free carriers as functions of frequency, temperature, and carrier and impurity concentrations.

24,344 NEW COLOR-CENTER BANDS IN THE ALKALI HALIDES by C.B. Pierce (Sandia Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 263(A), Mar. 1964

Recent investigations of 0 phonon lines and other fine structure associated with various complex color center bands in the alkali halides have led to the observation of new bands beyond the N bands in the IR in several salts. All of these new bands contain a prominent 0 phonon line at He temperature and, in some cases, other fine structure. The centers are produced at room temperature, generally by 2-Mev electron bombardment. Materials in which the bands have been observed and their 0-phonon-line positions are: LiF 8325 and 10,400 A, NaF 10,717 A, NaCl 14,042 A, and KCl 16,292 A. The 0-phonon-line positions fit the Ivey relation, $\lambda_{max} = 334d^{1.39}$ A, very well, except that the bands in LiF fall on either side of this line. In view of this agreement with the Ivey relations, which is found to hold for the F and F-aggregate centers, and since the only other bands showing similar structure (R_2 and N) are generally considered to be due to such centers, it was proposed that these new IR bands are due to the presence of still larger F-center complexes.

24,345 ABSORPTION BAND SHAPES FOR THE F CENTER AND THALLIUM IN KCl by C.C. Klick, D.A. Patterson, and R.S. Knox (U.S. Naval Res. Lab.); Phys. Rev., Vol. 133A, pp. A1717-1723, Mar. 16, 1964

The shape of the optical absorption band has been measured for the F center in KCl and for Tl^+ in KCl over a temperature range from 4°K to room temperature and over a range of absorption coefficients extending to 10^{-4} of the peak value. No evidence is found that Urbach's rule applies to the absorption bands of these centers. For the F center in KCl it is possible to describe the long-wavelength side of the absorption band over the full range of absorption using configuration coordinate diagrams in which one of the approximations usually employed has been eliminated. It then becomes possible to determine the configuration coordinate diagram from absorption measurements alone. The configuration coordinate diagram determined in this way, however, fails to predict the F-center emission spectrum correctly. Several possible reasons for this failure are discussed.

24,346 ON THE COLLOIDAL ABSORPTION BANDS IN RUBIDIUM CHLORIDE AND RUBIDIUM BROMIDE CRYSTALS COLOURED WITH SODIUM by V. Hovi and P. Ketolainen; Phys. Cond. Matter, Vol. 2, pp. 204-209, Apr. 1964

Colloidal absorption bands in rubidium chloride and rubidium bromide crystals colored with sodium have been investigated. After a certain heat treatment of the RbCl and RbBr crystals containing F-centers, colloidal bands were observed at 585 mμ for RbCl and at 600 mμ for RbBr. The measured positions of these bands were compared with those calculated by means of the theory of Doyle. Measurements of the areas of the absorption curves were also carried out at different temperatures.

24,347 SUM RULES IN THE THEORY OF EXCITON ABSORPTION OF LIGHT by I.P. Dzyub (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1144-1150, Dec. 1963

A method for determining the moments of the curve of exciton absorption of light is proposed. The first four moments are determined and their temperature dependence is investigated for the case of Wannier-Mott excitons. The connection between the asymmetry of the exciton absorption curve and the character of the exciton band is established, and the question of testing the conclusions of the theory is discussed.

24,348 ON THE INFRARED ABSORPTION THEORY IN CRYSTALS INCLUDING THREE-PHONON INTERACTIONS by V.N. Kashcheev (Acad. Sci. Latvian SSR); Soviet Phys.-Solid State, Vol. 5, pp. 988-994, Nov. 1963

An expression for the linear absorption coefficient of infrared radiation by a crystal with an arbitrary number of "optically active" branches is derived. An analysis is carried out of the frequency dependence of the absorption coefficient in different parts of the absorption region, caused by the third order anharmonicity of the oscillations.

24,349 THEORY OF INFRARED LIGHT ABSORPTION IN CRYSTALS. FOUR PHONON INTERACTION by V.N. Kashcheev (Acad. Sci. Latvian SSR); Soviet Phys.-Solid State, Vol. 5, pp. 1700-1704, Feb. 1964

The effect of fourth order anharmonicity on the frequency and temperature dependence of the coefficient of linear infrared absorption in ionic crystals is discussed. It is assumed that only one optical branch is active. The form of the temperature dependence found agrees with experiment. An examination of the frequency dependence shows that it is essentially the same as the case where only third order anharmonicity is taken into account.

24,350 LOCALIZED VIBRATION DUE TO BORON AND LITHIUM IN THE SILICON LATTICE by M. Balkanski and W. Nazarewicz (Lab. Phys. l'Ecole Norm. Sup., Paris); J. Phys. Chem. Solids, Vol. 25, pp. 437-441, Apr. 1964

The infrared absorption spectrum of silicon crystals containing two electrically compensated impurities, boron and lithium, in concentrations above the 10^{19} per cm^3 reveals six absorption peaks at: 648, 657, 585, 564, 534 and 522 cm^{-1} attributed to localized vibrations due to those impurities.

24,351 FAR-INFRARED ABSORPTION IN SUPERCONDUCTING LANTHANUM by J.D. Leslie, R.L. Cappelletti and D.M. Ginsberg (U. Illinois), D.K. Finnemore, F.H. Spedding and B.J. Beaudry (Iowa State U.); Phys. Rev., Vol. 134A, pp. A309-311, Apr. 20, 1964

Measurements have been made of far-infrared absorption in pure, face-centered cubic, superconducting lanthanum at 1.3°K. The results indicate a gap width $2\Delta = 12.0 \pm 1.0$ cm^{-1}. In terms of the measured value of the critical temperature, $T_c = 6.06$°K, $2\Delta = 2.85 \pm 0.24\ kT_c$. The data indicate the possible presence of a small amount of structure in the absorption curve at an energy about twice the gap width. These results are compared with theoretical predictions which have been made recently from a proposed new mechanism for superconductivity in lanthanum.

24,352 THE INFRARED SPECTRA OF MICAS IN THE 1000-650 cm^{-1} REGION AND ITS DEPENDENCE ON CRYSTAL ORIENTATION by J. Serratosa and A. Hidalgo (Inst. Edafologia, Spain); Appl. Optics, Vol. 3, pp. 315-316(L), Feb. 1964

The dependence of the infrared spectra of micas in the 1000-650 cm^{-1} region has been investigated. The absorption spectra of four different types of mica were examined, and each spectrum was determined for two different flake angles and for the mica powder imbedded in a KBr pellet. The additional absorption bands which appear for the case of the flake at non-zero incidence angles were also observed for each powder. The latter would be expected to exhibit all permissible absorption frequencies. The additional band between 805 and 830 cm^{-1} is attributed to a vibration of the tetrahedral layer. An explanation is advanced for the non-occurrence of the effect for micas in a diamond cell or in paraffin oil.

24,353 FREE-CARRIER INFRARED ABSORPTION IN III-V SEMICONDUCTORS. Part II. InAs by E. Haga and H. Kimura (Nagoya U.); J. Phys. Soc. Japan, Vol. 19, pp. 471-481, Apr. 1964

An analysis of the infrared absorption by free carriers in n-type InAs is carried out on the basis of a previous theory developed for n-type InSb, in order to investigate the scattering mechanism. The magnitude of the deformation potential constant E_1 is found to be 10 ev, and it is found that the contribution from acoustical phonons is not important for all samples of Dixon. The impurity concentration is found to be $N_{imp} = 11\ N_e$ for the sample A of the smallest carrier concentration: $N_e = 2.8 \times 10^{16}$ cm^{-3}, and to be $N_{imp} = N_e$ for the other samples. Optical phonons make the most important contribution for samples of relatively low carrier concentrations except the sample A, in which the contribution from impurities is comparable to the one from optical phonons. The presence of an unknown scatterer in the sample A is suggested and a discussion for this is given. A discussion on the screened Coulomb potential used in the calculation of the impurity scattering also is given.

24,354 INFRARED ABSORPTION SPECTRUM OF $NaNO_2$ SINGLE CRYSTALS AFTER GAMMA-RAY IRRADIATION by K. Gesi and Y. Takagi (Japan AE Res. Inst.); Japanese J. Appl. Phys., Vol. 3, pp. 126-127(L), Feb. 1964

The change in absorption spectra of a single crystal of $NaNO_2$ irradiated at room temperature with 3×10^8r of Co^{60} gamma radiation has been measured with polarized infrared light. The radiation-induced absorption bands are too strong to be attributed to point defects introduced through radiolytic decomposition of NO_2^-. It is postulated that an absorption band polarized in one direction in an unirradiated crystal is observable in the other two directions after irradiation

24,355 INFRARED SPECTRAL TRANSMITTANCE OF MgO AND BaF_2 CRYSTALS BETWEEN 27° AND 1000°C by U. Oppenheim and A. Goldman (Israel Inst. Tech.); J. Optical Soc. Am., Vol. 54, pp. 127-128(L), Jan. 1964

The optical properties of MgO and BaF_2 crystals have been determined between room temperature and 1000°C. Curves of transmittance versus wavelength are given for each crystal. The spectral absorption coefficient K_λ is also plotted as a function of wavelength. Results show that BaF_2 is superior to MgO as a window material with a long-wavelength limit of 9 μ.

Infrared Transmission in CoF_2, NiF_2 and $MnCO_3$ - See 24,250

24,356 IMPURITY-INDUCED FAR-INFRARED ABSORPTION IN ALKALI HALIDES by A.J. Sievers (Cornell U.); Bull. Am. Phys. Soc., Vol. 9, p. 228(A), Mar. 1964

The far-infrared transmission of alkali halide crystals doped with heavy- and light-mass impurities has been measured from 100 to 10 cm^{-1} at liquid-helium temperatures. Two absorptions have been found in thallium-doped potassium iodide: a line at 65.2 ± 0.7 cm^{-1} with a width at half-maximum of 2 cm^{-1} and a broader absorption centered at 55 ± 1 cm^{-1}. The strengths of both lines vary with thallium concentration. Two similar absorptions have been observed in thallium-doped sodium iodide at 77.4 ± 1 and 67 ± 1.5 cm^{-1}, respectively. These frequencies appear to be located in the gap between the acoustic and optic branches. The light-mass impurity has been studied in potassium iodide plus hydride (U center). An absorption at 61.2 ± 0.7 cm^{-1} has been identified with the U center since photochemical conversion of the U to F centers by irradiation in the U band decreases the far-infrared absorption intensity. In addition, conversion of F to U with heat restores the original absorption strength.

24,357 EFFECT OF A STRONG ELECTRIC FIELD ON THE ABSORPTION OF ELECTROMAGNETIC MICROWAVE RADIATION IN PHOTOSENSITIVE LAYERS OF LEAD SULFIDE by S.N. Chechurin (Leningrad State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1721-1722, Feb. 1964

Experimental data on the dependence of the absorption of 3-cm radiation in PbS photoresistors on the magnitude of the voltage applied to the layer is reported. The data indicate that the conductivity of the layer is reduced with increasing applied voltage, which is shown to be caused by the change of the carrier mobility in strong electric fields.

Absorption in:
Al_2O_3 - See 23,718
GaAs - See 24,421
GaP - See 24,401

Transmission in Group IV-VI Compounds and Group V Semimetals - See 24,435

24,358 A MEASUREMENT OF THE TEMPERATURE DEPENDENCE OF THE ABSORPTION EDGE OF SINGLE CRYSTALS, USING POLARIZED LIGHT by R. L. Dunham (Texas A and M); Jan. 1964, 27 pp.; U.S. Gov. Res. Rep., Vol. 39, p. 118(A), Apr. 20, 1964 AD 428 254 OTS $3.60

An attempt to measure the absorption edges of single crystals of iodine as a function of temperature, using polarized light, was primarily unsuccessful. Electronic noise which could not be eliminated prevented the recording of any useful information. The substitution of a photomultiplier which had a spectral response in the visible spectrum for the one with spectral response in the infrared made possible the measurement of the absorption edge of single crystals of cadmium sulfide. The cadmium sulfide measurements were in close agreement with published data.

24,359 OPTICAL-ABSORPTION EDGE IN CdTe: EXPERIMENTAL by D.T.F. Marple and B. Segall (GE); Bull. Am. Phys. Soc., Vol. 9, p. 223(A), Mar. 1964

Previous optical-absorption-edge studies have indicated that the smallest band-gap in CdTe is "indirect." However, optical and electrical data and cyclotron resonance suggest that it is "direct." To try to better understand the nature of the edge, the optical transmission near the absorption limit was studied in several CdTe single crystals of suitable thicknesses at temperatures from 2.1° to 173°K, with resolution of 10^{-3} ev or less. Chemical polishing of mechanically polished samples was found essential to obtain consistent results. Absorption

bands found near the band edge in Te-fired samples or impure sections of zone-refined crystals lead to spectra resembling those already reported. In spectra obtained with the purest crystals, where these bands are weak or absent, an indirect bandgap cannot account for the observed temperature and wavelength dependence of the absorption. Thus, the smallest indirect bandgap energy must equal or exceed the direct-exciton energy.

24,360 OPTICAL-ABSORPTION EDGE IN CdTe: THEORETICAL by B. Segall and D.T.F. Marple (GE); Bull. Am. Phys. Soc., Vol. 9, p. 223(A), Mar. 1964

The intrinsic absorption in CdTe at energies just below the first exciton line was shown to be interpretable as "direct"-exciton absorption accompanies by the annihilation of phonons. From about 40°K (where relevant optical-phonon effects can become significant) to about 80°K, the absorption constant can be fitted by the theory of Dietz et al., for the simultaneous absorption of the photon and a single, longitudinal optical phonon. Agreement with the observed absorption edge is achieved by using previously determined values for the longitudinal optical-phonon energy, high- and low-frequency dielectric constants, temperature-dependent exciton energy, exciton binding energy and oscillator strength, electron effective mass, and a reasonable value for the undetermined hole mass of approximately 0.3. At about 80°K and above, the 1-phonon process does not account for all the observed absorption. The absorption constant due to the annihilation of 2 longitudinal optical phonons simultaneously with the photon has been calculated. Including this contribution, the theory satisfactorily accounts for the data.

24,361 ABSORPTION EDGE OF ZnSb by M. Zaverova (Czech. Acad. Sci. Prague), Phys. Status Sol., Vol. 5, pp. k19-21, 1964

The optical absorption edge of p-type ZnSb single crystals has been studied in the energy range of 0.46 to 0.69 ev at room temperature in directions perpendicular to the crystallographic axes a, b and c. It is shown that the frequency dependence of the absorption in ZnSb is similar to that of CdSb. This similarity is accounted for in terms of similarity in chemical bonds in these two compounds. The energy of the indirect gap in ZnSb is approximately 0.48 for all three polarizations of the incident radiation used.

24,362 OPTICAL PROPERTIES OF SILICON CARBIDE CRYSTALS by I.S. Gorban' and S.N. Rud'ko (Sherchenko State U.); Soviet Phys.-Solid State, Vol. 5, pp. 995-998, Nov. 1963

The structure of the long-wavelength fundamental absorption edge, the ultraviolet spectrum and the properties of photoluminescence of synthetic and technical-grade silicon carbide crystals have been investigated. The structure of the edge is ascribed to indirect transitions with participation of three types of phonon. The properties of the absorption spectrum in the ultraviolet indicate the complex structure of the electron bands. It is found that silicon carbide crystals exhibit photoluminescence of two types which differ in the energy distribution in the spectrum, the temperature dependence of the intensity and in the excitation spectra.

Absorption:
Edge in ZnSb - See 24,323
in KBr - See 23,914

RADIATION AND LUMINESCENCE

24,363 RAMAN EFFECT IN THE F CENTER by D.A. Kleinman (Bell Labs.); Phys. Rev., Vol. 134A, pp. A423-426, Apr. 20, 1964

A discussion is given of the theory of the Raman effect in the F center. It is shown that the study of this effect could give new information about the F center that might lead to an understanding of its long radiative lifetime.

24,364 STIMULATED EMISSION IN AROMATIC ORGANIC COMPOUNDS by D. Stockman, W. Mallory (GE, Syracuse) and K. Tittel (GE, Schenectady); Proc. IEEE, Vol. 52, pp. 318-319(L), Mar. 1964

The various spontaneous emission processes occurring in aromatic organic compounds are considered. The relative advantages of a fluorescent as compared to a phosphorescent liquid or solid-state system for achieving laser action is discussed. A very promising candidate for a 4-level fluorescent laser system is the molecule perylene.

24,365 POLARIZED EMISSION OF Sm^{2+} IN THE ALKALI HALIDES by W.E. Bron and W.R. Heller (IBM Res. Ctr.); Bull. Am. Phys. Soc., Vol. 9, p. 228(A), Mar. 1964

Previously reported studies of the crystal-field splittings of the $4f^6 \rightarrow 4f^6$ transitions of the Sm^{2+} in the alkali halides had shown that the Sm^{2+} site symmetry is C_{2v}. This is consistent with the presence of a cation vacancy as nearest neighbor to the Sm^{2+}. In order to make crystal-field-term assignments to the levels of the $4f^6$ configuration, polarized emission has now been studied for the transitions within the configuration. Excitation with linearly polarized monochromatic light with wavelength in one of the absorption bands of the transition $4f^6 \rightarrow 4f^5d$ was used. The 6328-A line of the He-Ne laser was found particularly suitable for this purpose. The polarization results confirm the 2-fold symmetry axis of the Sm^{2+} and make possible determination of crystal-field coefficients. Polarized excitation light with 90 A width or more was found to yield only unpolarized emission. The most likely reason for this result is that the absorption band contains a number of closely spaced energy levels that either correspond to weakly split states of the $4f^5$ core or are vibronic in origin.

24,366 RECOMBINATION RADIATION FROM DIAMOND by P.J. Dean and I.H. Jones (King's Coll., London); Phys. Rev., Vol. 133A, pp. A1698-1705, Mar. 16, 1964

The spectrum of the recombination radiation from diamond has been measured over the photon energy range 4.9-5.5 ev at 90, 160, 207, and 320°K. The persistent and usually dominant spectral features are interpretable in terms of exciton annihilation with the emission into the lattice of one or more phonons. The energies of the single phonons and the proposed classifications are 0.085 ev (transverse acoustical), 0.134 ev (longitudinal optical and acoustical), and 0.142 ev (transverse optical). The magnitudes of the experimental intervalley phonon energies show that the conduction band minima of diamond are situated at about 95% of the distance from the center of the Brillouin zone to the zone boundary in the <100> directions. Recombination emission bands are also observed which appear respectively to involve at the low-energy extremities the simultaneous emission of two or three phonons of energy comparable to the Raman energy (0.065 ev). Two sets of sharp two-component extrinsic recombination bands are present. Each component of a given set is displaced by approximately the same energy below the low-energy thresholds of the intrinsic longitudinal acoustical (LA) + longitudinal optical (LO) and transverse optical (TO) bands (displacement energies 0.056 and 0.009 ev). These bands are thought to arise from the recombination of excitons bound to certain impurity or defect sites. One system (0.056 ev binding energy) is tentatively associated with the acceptor center of semiconducting (type IIb) diamond, which is thought to be substitutional aluminum. The anticipated corresponding recombination bands occurring without the emission of a phonon have not been identified, however.

24,367 EFFECT OF A MAGNETIC FIELD ON THE RECOMBINATION RADIATION FROM Ge AND ITS QUENCHING BY INFRARED RADIATION by I.K. Kikoin and Yu.P. Kozyrev; Soviet Phys.-JETP, Vol. 18, pp. 962-963, Apr. 1964

The recombination radiation from Ge placed in a magnetic field has been studied at 77°K. The intensity of the recombination radiation decreased under the influence of the magnetic field. It is observed that quenching of the radiation occurred when the specimen was illuminated by infrared radiation in the spectral region outside the absorption edge of germanium, while the relative change of the intensity due to the magnetic field was not affected by the infrared background illumination.

24,368 QUANTUM EFFICIENCY OF A NEW GaAs SPONTANEOUS INFRARED SOURCE by W. Carr and G. Pittman (Texas Instr.); Proc. IEEE, Vol. 52, pp. 204-205(L), Feb. 1964

The external efficiency of injection luminescence for a new GaAs device geometry is reported. Efficiency data have been obtained over a temperature range extending from 4.2° to 270°K for radiation through a vacuum dielectric. The new domed source geometry has been found to provide an order of magnitude increase in efficiency over that measured with typical rectangular (flat) geometries. A silicon solar cell with calibrated quantum detection efficiency was used in the measurements. Typical quantum efficiency values ranging from about 15% at 4.2°K to about 1% at 400°K were observed.

24,369 EFFICIENCY OF RECOMBINATION RADIATION IN GaP by H.G. Grimmeiss and H. Scholz (Philips); Phys. Lett., Neth., Vol. 8, pp. 233-235(L), Feb. 15, 1964

The quantum efficiency of p-n luminescence in GaP alloyed diodes doped with zinc and exygen is discussed. The current-voltage characteristics of the diodes were measured at 298° and 77°K. From these measurements and simultaneous measurements of the short circuit current of a photocell excited by the GaP radiation, room temperature values of η was determined to be approximately 1.5 per cent. Subsequent measurements made with the diodes immersed in liquids of different refractive indices indicated that the amount of light emitted by the diode is limited by the high refractive index of GaP. When the refractive index of GaP is considered, more than 0.2 photon is released per injected electron. The high absorption of the 7000 A emission by the zinc and oxygen impurities, and the variation of the emission intensity as a function of the current through the p-n junction further indicate that η is near unity.

24,370 KINETICS OF RADIATIVE RECOMBINATION IN GaP p-n JUNCTIONS AT FORWARD BIAS by M. Gershenzon, R.A. Logan, D.F. Nelson and D.G. Thomas (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 236(A), Mar. 1964

In a series of reproducible diodes the energy distribution of the radiation emitted at forward bias was studied as a function of current, bias, and temperature. Near room temperature, the spectra consisted of the "A" line previously described and a red band at 1.8 ev. The dependence of the latter on current consisted of two regions separated by a sharp knee that always occurred at an applied potential of 1.7 v at 300°K, independent of diode preparation. The temperature variation of this critical bias equalled that of the bandgap. Below the knee, the 1.8 ev radiation depended upon potential as exp ev/kT (while current varied as exp ev/nkT with $1 < n < 2$). Above the knee, the light output was linear in current. These relations held for junctions diffused both at 825° and 1025°C, despite the fact that the external quantum efficiencies were 10^{-4} and 10^{-6}, respectively. These results may be interpreted as arising from radiative recombination from a 0.4-ev level, perhaps the deep donor previously associated with oxygen, and the crossing of this level by the quasi-Fermi level to produce the sharp knee.

24,371 RADIATIVE RECOMBINATION IN PbTe by E.R. Washwell and K.F. Cuff (Lockheed Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 293(A), Mar. 1964

Photoinduced band-to-band recombination radiation has been observed in PbTe. The measurements were made on both n- and p-type single crystals that were well-annealed and etched. The recombination radiation was observed from the illuminated surface; the measurements covered the temperature range of 20° to 300°K, and the spectral region 0.12 to 0.35 ev. The spectrum consists of a single line with considerable structure superimposed. For p-type PbTe ($p = 2 \times 10^{18}/cm^3$), the emission peak occurs at 0.24 ev at 100°K and has a nearly temperature-independent width of 0.04 ev. The position of the emission peak has approximately the same temperature dependence as the gap. The superimposed structure appears to be associated principally with multiple longitudinal optical-phonon emission. Radiative recombination has also been detected in PbSe and the preliminary data indicate structure and behavior similar to that observed in PbTe.

Photoluminescence of SiC - See 24,362

24,372 INJECTION ELECTROLUMINESCENCE IN ZnS AND ZnSe by M. Aven and D.A. Cusano (GE Res. Lab.); J. Appl. Phys., Vol. 35, pp. 606-611, Mar. 1964

Injection electroluminescence has been observed in Cu_2S-ZnS and Cu_2Se-ZnSe heterojunctions. The light emission occurs through hole injection from the p-type Cu chalcogenide into n-type ZnS or ZnSe. At room temperature the light emission from the Cu_2S-ZnS and the Cu_2Se-ZnSe junctions originates at the Cu or self-activated luminescence centers. At 77°K the Cu_2Se-ZnSe diodes exhibit emission bands peaking at 1.96, 2.07, 2.36, and 2.68 ev. The dominance of any one of these bands over the others can be achieved by appropriate preparative techniques. In the diodes emitting predominantly in the 2.36-ev band the light intensity varies approximately as the 3/2 power of current. The lowest voltage threshold observed for visible light emission is 1.5 v. Both the luminescence and the electrical characteristics of the prepared diodes are in accord with a tentative model for the band structure of Cu chalcogenide-II-VI compound heterojunctions. The particular model for the Cu_2Se-ZnSe diodes is presented and discussed in detail.

24,373 LOW-TEMPERATURE RECOMBINATION LUMINESCENCE IN ALKALI HALIDES by M.N. Kabler (U.S. Naval Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 241(A), Mar. 1964

X-irradiation of KCl at 4°K has been observed to induce luminescence in a band centered at 2.31 ev. In crystals containing F and V_K centers (self-trapped holes), this same luminescence may be excited by light in the F absorption band, which is overlapped on both high- and low-energy sides by the broader emission spectrum. If the V_K centers have been preferentially oriented, the luminescence excited by unpolarized F light is 30 per cent polarized. Evidence supports a simple electron-hole recombination model, the hole being self-trapped in the lattice. X-rays excite the luminescence directly, but F-light excitation must involve tunneling of the F electron to a V_K center.

24,374 VOLTAGE DEPENDENCE OF THE AVERAGE BRIGHTNESS OF ELECTROLUMINESCENCE by I.K. Vereshchagin; Optics and Spectroscopy, Vol. 16, pp. 157-161, Feb. 1964

Assuming that in barrier layers of crystals (metal contacts or p-n junctions) collisional ionization takes place under the control of the diffused reverse current of the barriers, expressions for the average luminescence brightness for various methods of exciting electroluminescence (Losev and Destriau effects) are obtained. The calculations take into account the influence of ionization rate on the distribution of external voltage between the barrier and the remaining parts of the crystal. Expressions obtained for brightness agree well with the results of measurements on ZnS and ZnO.

24,375 ELECTROLUMINESCENT PROPERTIES OF LUMINORS ON A ZINC-CADMIUM-SULFOSELENIDE BASE by I.A. Mironov and L.Ya. Markovskii; Optics and Spectroscopy, Vol. 16, pp. 155-157, Feb. 1964

The results of an investigation of the properties of electroluminors with red luminescence on zinc-cadmium-sulfoselenide bases are presented. A study was made of the spectral distribution of the radiation and the brightness of the luminescence as functions of the ratios of components in the base of the liminor and the operating conditions of the electroluminor (frequency of the excitation and temperature).

24,376 ELECTROLUMINESCENT PROPERTIES OF Zn(S:Se):Cu TYPE PHOSPHORS [in French] by S. Asano and Y. Nakao (U. Okayama); Japanese J. Appl. Phys., Vol. 3, pp. 137-143, Mar. 1964

The spectral distribution, temperature dependence and voltage dependence were measured on electroluminescent phosphors Zn(S:Se) activated with Cu and Cl, and those activated with Cu and Al. In addition, some thermoluminescence measurements were made, which are important in interpreting the electroluminescent behaviors. The phosphors containing a large proportion of ZnSe show pronounced temperature quenching at room temperature. Their emission band broadens considerably and tends to be separated into two bands at 77°K. The experimental results suggest that the ionized centers in these phosphors tend to recombine with electrons in valence band by thermal excitation.

24,377 ON THE COMBINED EFFECT OF SHORT ELECTRIC PULSES AND SINUSOIDAL VOLTAGE ON THE ELECTROLUMINESCENCE OF ZnS-Cu PHOSPHOR by F.I. Kolomoitsev and V.M. Korsun; Optics and Spectroscopy, Vol. 16, pp. 49-51, Jan. 1964

The electrical conductivity and luminescence of ZnS-Cu when sinusoidal and pulse excitation are applied simultaneously to an electroluminescent condenser filled with the powdered phosphor and a liquid dielectric have been studied. The phase position and amplitude of the pulse were varied over a wide range. It was proved that the excitation and recombination of luminescence centers takes place at different phases of the applied voltage. The continuous currents act like injection currents and are responsible for the excitation of the phosphor.

24,378 LOW-FIELD ELECTROLUMINESCENCE IN ZnS:Cu CRYSTALS by I. Dev (U. Hull, England); Bull. Am. Phys. Soc., Vol. 9, p. 224(A), Mar. 1964

Electroluminescence measurements were made on ZnS:Cu crystals excited by low ac and dc fields. When alternating fields were applied across a 1-mm gap on the crystal surface, detectable emission was observed in several crystals at 4.5 v (rms). These low-threshold voltages were observed only when the electric field was applied perpendicular to the c axis of the crystal. The brightness-frequency relationship was complicated, but generally the slope of logB-log f curves changed from negative to plus 0.3 as voltage was raised. Brightness-voltage relationship was more often a power law rather than $B \propto \exp(V)^{-1/2}$. Threshold voltages for dc excitation were 2 to 3 times higher than for ac fields, though one crystal emitted light at 4.5 v dc. The brightness-current relationship was $B \propto I^m$, $1 < m < 2$ and the brightness-voltage relationship was $B \propto V^n$, $3 < n < 5$.

24,379 FREQUENCY DEPENDENCE AND MECHANISM OF ELECTROLUMINESCENCE IN ZnS (Cu,Al) ELECTROLUMINESCENT PHOSPHORS by K. Miyashita, M. Wada, and T. Takahashi (Tohoku U.); Japanese J. Appl. Phys., Vol. 3, pp. 1-10, Jan. 1964

It is confirmed that the empirical equation $B = B_0 \exp(-C/\sqrt{V})$ is applicable to the electroluminescent emission from ZnS (Cu,Al) EL phosphors embedded in a dielectric. Then, based on this equation, the frequency dependence of the electroluminescent emission is discussed in detail. The quantities B_0 and C in the above equation are considered with respect to frequency and temperature. According to the experimental results obtained, the emission mechanisms of electroluminescence in this phosphor are considered, principally on the exciting high field, the primary electron source and the recombination process. Finally, it is concluded that primary electrons may be injected through the depletion layer by the tunnel effect and that the recombination process may act on the monomolecular law.

24,380 KINETICS OF ELECTROLUMINESCENT DETERIORATION IN SOME ZnS PHOSPHORS by L.A. Rogers (Corning Glass Works); J. Electrochem. Soc., Vol. 111, pp. 411-412, Apr. 1964

The deterioration of ZnS:Cu:halogen electroluminescent phosphors with time is shown to follow second order kinetics. The activation energy for deterioration was found to be about 11 kcal/mole for three chloride coactivated phosphors and 23 kcal/mole for one bromide coactivated phosphor.

24,381 THE MECHANISM AND KINETICS OF THE ELECTROLUMINESCENCE OF CUPROUS OXIDE by Yu.I. Karkhanin and Yu.V. Vorob'ev (Shevchenko Kiev State U.); Soviet Phys.-Doklady, Vol. 8, pp. 975-977(L), Apr. 1964

The infrared electroluminescence of Cu_2O excited under various conditions has been investigated. It is shown that there are no grounds for the idea of the existence of two different kinds of electroluminescence. Comparison of the kinetics of the photo- and electroluminescence supports the hypothesis that the elec-

troluminescence of Cu_2O in all cases is due to the injection of electrons from the cathode.

24,382 ELECTROLUMINESCENCE IN OXIDE PHOSPHORS by S. Jones (GE, Cleveland); J. Electrochem. Soc., Vol. 111, pp. 307-311, Mar. 1964

Certain oxide phosphors have been observed to exhibit substantial electroluminescence (EL) in high electric fields. This electroluminescence may be induced either by an alternating field, in which case insulating films may be interposed between the phosphor and the electrodes, or by a direct field, in which case an insulating film between the electrodes is not permissible. The voltage required is about 20 times that needed for equal brightness in commercial EL lamps using copper-activated zinc sulfide phosphors.

24,383 NORMALIZATION OF THERMOLUMINESCENCE DATA by W.L. Medlin (Socony Mobil); Am. Mineralogist, Vol. 49, pp. 53-60, Jan.-Feb. 1964

In measuring the intensity of thermoluminescence in rock samples, variations in self absorption within the sample must be accounted for. Two methods for doing this are described. One consists of mixing a thermoluminescent internal standard with the sample. The other involves measuring the diffuse reflectance of the sample in powder form and computing an appropriate normalization factor. A method is also described which corrects for transparency changes in a single sample due to heating.

24,384 MEASUREMENT OF THERMOLUMINESCENCE WITH A DOUBLE BEAM SPECTROMETER [in German] by G.O. Brunner (Inst. Kristallographie and Petrographie); Helv. Phys. Acta, Vol. 37, pp. 51-54, 1964

The conversion of a commercial 'low cost' spectrometer for measurement of thermoluminescence is described. The main features of the instrument are: (a) suppression of the measured 'black body' radiation by a factor of 100 by the double beam technique, (b) possibility of spectral investigation of the radiation, and (c) strong demagnification of the beam permits use of small sample quantities (approx. 1 mg).

24,385 THERMOLUMINESCENT KINETICS OF ALPHA-IRRADIATED ALKALI HALIDES by C.E. May and J.A. Partridge (Lewis Res. Ctr.); J. Chem. Phys., Vol. 40, pp. 1401-1409, Mar. 1, 1964

The kinetics of the thermoluminescence of single crystal NaCl, KCl, and KBr irradiated with 40-Mev alpha particles were investigated. Only one glow peak, composed essentially of a single emission band, was obtained for each of the salts investigated. To attempt complete analysis of the kinetics, both glow curve and isothermal annealing experiments were employed. The results from glow curves were shown to be unreliable for calculation of the kinetic order in the case of NaCl and KBr. The isothermal tests indicate the kinetics of the dominant process for NaCl to be first order; for KBr, first order; and for KCl, 3/2 order. No general statement can be made concerning the order of these processes; thus, at present, the kinetics for each salt investigated must be determined individually. Occasionally, secondary processes occur in specimens of NaCl and KBr, even though essentially only one spectral peak was detected. A simple model for luminescence will explain the kinetics of NaCl and KBr; it involves activation of electrons from traps into the conduction band. To explain the results for KCl, a more complex model is required. Activation energies were also calculated.

24,386 SCINTILLATIONS IN THE THERMOLUMINESCENT LIGHT FROM KDP AND TRIGLYCINE SULFATE by H.P. Yockey (Hughes Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 215(A), Mar. 1964

KDP crystals irradiated by X-rays at liquid-nitrogen temperature exhibit scintillations in the thermoluminescent-glow peak between about 130° and 150°K. A normal continuous-glow peak appears at 213°K. Oscilloscope pictures of the scintillations show a bellshaped pulse of about 4×10^{-8} sec duration for pulses of all sizes. The total energy associated with some scintillations was found to be at least 1.5×10^5 ev in crystals exposed to 9000 R. Experiments with Wratten filters show that the major portion of the light lies in the region 4600 to 6000 A. Triglycine sulfate X-rayed at room temperature shows the same phenomenon between 25° and 64°C. The pulse is also bellshaped and is of 4×10^{-8} sec duration. A pulse-height analysis for triglycine sulfate shows a distribution decreasing monotonically toward higher pulse heights. This phenomenon was found in GASH and Rochelle salt and may be typical of the hydrogen-bonded ferroelectrics.

24,387 SOME EFFECTS OF PRESSURE ON THE THERMOLUMINESCENCE OF AMBLYGONITE, PECTOLITE, ORTHOCLASE, SCAPOLITE AND WOLLASTONITE by E.E. Angino (Texas A and M); Am. Mineralogist, Vol. 49, pp. 387-394, Mar.-Apr. 1964

The effects of shearing pressures on the natural thermoluminescence of several minerals have been studied. Pressure applied uniaxially and producing shear stress of unknown magnitude, decidedly affects the natural thermoluminescence of amblygonite, orthoclase, pectolite, scapolite and wollastonite. In all instances the peak temperatures of the natural glow curves are gradually shifted 40° to 60°C with increasing pressure. (In some minerals the shift is upward, in others downward). The ratio of light intensity of the middle (260° to 315°C) to high temperature (335° to 405°C) thermoluminescence after pressure treatment remained essentially constant. It is suggested that detailed investigation of the effects of pressure and time on the thermoluminescent glow curve characteristics of different rocks and minerals may be useful in the study of pressure and temperature distributions in rock materials surrounding (and affected by) both underground nuclear explosions and also intrusive bodies.

24,388 THE CATHODOLUMINESCENCE OF Mn^{2+} AND Fe^{3+} -ACTIVATED MAGNESIUM ALUMINATE SPINEL by F.A. Hummel and J.F. Sarver (Penn. State U.); J. Electrochem. Soc., Vol. 111, pp. 252-253(L), Feb. 1964

The effect of small concentrations of isoelectronic ions such as Mn^{2+} and Fe^{3+} on cathodoluminescence in $MgAl_2O_4$ (spinel) lattice has been studied. The relation between such emission and the activator environment is discussed, taking account of the preference of Fe^{3+} ions for tetrahedral sites in ferrite spinel. The band widths of the green bands of Mn^{2+} and Fe^{3+} are almost identical, indicating that their centers have very similar crystallographic environments and energy difference characteristics.

24,389 CATHODOLUMINESCENCE OF RUBY by A. Kamal, M. Levine and G. Fuller (Purdue U.); Proc. IEEE, Vol. 52, p. 329(L), Mar. 1964

The use of low-energy (< 25 kev) electron beam bombardment to produce intense sharp-line fluorescence in ruby is described. Measurement of fluorescent efficiency and absolute fluorescent power from both the 6934 A and 6919 A lines for a beam power of 15 watts (E_{beam} = 18,000 volt, I_{beam} = 0.8 ma) indicates an output of approximately 15 mw for a conversion efficiency of about 0.1 per cent. Since the fluorescence is presumed to emitted from a surface layer no more than 10μ deep in the ruby rod, for a beam diameter of 1 cm, the fluorescent power density was approximately 20 watts/cm^3. The possibility of a pulse- or amplitude-modulated electron-beam-pumped optical maser is suggested.

24,390 PHOTOELECTROLUMINESCENCE OF ZINC SULFIDE SINGLE CRYSTALS by R. Taagepera and F. Williams (U. Delaware); Bull. Am. Phys. Soc., Vol. 9, p. 224(A), Mar. 1964

Radiation-controlled electroluminescence (photoelectroluminescence) has been observed in manganese-activated zinc sulfide single crystals. Ultraviolet radiation initiates electroluminescence; without ultraviolet, no electroluminescence is detectable for these crystals. As with vapor-deposited films, the emission intensity per unit flux of ultraviolet is greatest for low ultraviolet intensity and high voltage and the emission spectrum is shifted to shorter wavelengths. Electrodes conductively coupled to the crystal and with at least 500 v between them are used. The luminescent emission is localized at the cathode or at crystalline imperfections. With a point-contact cathode on a relatively homogeneous crystal, the emission occurs throughout the spreading resistance region where the local field exceeds $10^4 v \cdot cm^{-1}$. In addition to the ordinary photoconductive effects, it was proposed that the creation of free electrons and bound holes by the ultraviolet increases the positive space charge, thus reducing the width of the contact barrier, facilitating injection by tunneling. The injected electrons are then accelerated in the spreading resistance region where luminescence occurs.

24,391 PHOTOLUMINESCENCE OF InAs by A. Mooradian and H.Y. Fan (Purdue U.); Bull. Am. Phys. Soc., Vol. 9, p. 237(A), Mar. 1964

Photoluminescence of n-type ($n = 2 \times 10^{16}$ to 1.6×10^{17} cm^{-3}) and Zn-doped p-type InAs ($p \sim 2 \times 10^{17}$ cm^{-3}) was studied at low temperatures under magnetic fields up to 30 kg. At 77°K, n-type samples showed an emission band above 0.40 ev, which is characteristic of electron-hole recombination, becoming broader and shifting to higher energy with increasing carrier concentration. An additional peak at 0.399 ev was observed in some samples. At 4.2° and 1.6°K impurity peaks were observed at 0.402 ev in n-type and at 0.396 and 0.381 ev in p-type samples. There was also emission peaking at 0.410 ev or higher that appeared to be intrinsic recombination; the band in n-type samples was considerably narrower than at 77°K, showing the effect of the energy distribution of excited holes. In n-type samples, this band consisted of two peaks, ~0.411 and 0.415 ev, that became well-resolved under magnetic field. The 0.411-ev peak seems to be exciton emission. Under magnetic field, the bands sharpened and shifted to higher energy by about 0.003 ev at 30 kg.

24,392 L FLUORESCENCE YIELDS IN HEAVY ELEMENTS by J.W. Halley and D. Engelkemeir (Argonne Lab.); Phys. Rev., Vol. 134A, pp. A24-28, Apr 6, 1964

L X-ray fluorescence yields for the Ra, Th, U, Pu, and Cm daughters of even-even alpha emitters were measured by three methods. Internal conversion of E2 gammas from the decay of these nuclides produces approximately equal numbers of L_{II} and L_{III} vacancies and practically no L_I vacancies; the yields reported here are, therefore, averages of the L_{II} and L_{III} shell yields. The results are: Ra, 0.480±0.012; Th, 0.488±0.008; U, 0.478±0.009; Pu, 0.540±0.009; and Cm, 0.531±0.010.

24,393 MAGNETIC SPLITTING OF EDGE-EMISSION LINES IN CdSe by D. C. Reynolds and C.W. Litton (Aerospace Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 224(A), Mar. 1964

Zeeman effects have been observed in several of the sharp, short-wavelength, characteristic edge-fluorescence lines of selected CdSe platelets at magnetic fields up to 45,000 G and at temperatures near 1°K. These CdSe lines, which appear in the spectrum between the broad phonon-assisted peaks and the ground-state exciton (6790 A) of the first series, are similar in both appearance and magnetic behavior to several of the intrinsic lines in CdS, which have previously been reported and attributed to exciton complexes. One of the lines appears at 6821 A and splits with a g value of approximately 0.5 for $c \perp H$, which is in good agreement with the previously reported g value for electrons in CdSe. Two other lines appearing at 6827 and 6884 A are also sharp but relatively weak. These lines also split linearly but split as quartets. This type of splitting has not been observed in any of the CdS transitions that have been investigated. The emission-line splittings at different orientations of the crystalline c axis with respect to the magnetic-field direction are discussed.

24,394 SPECTRAL PROPERTIES OF RARE EARTH OXIDE PHOSPHORS by R.C. Ropp (Sylvania); J. Electrochem. Soc., Vol. 111, pp. 311-317, Mar. 1964

A study of rare earth oxide phosphors activated by rare earths revealed that fluorescence occurs only in those matrices where the cation possesses no unpaired electrons. The fluorescent intensities of the rare earth activators were divided into three categories: strong, medium, and weak, each having a characteristic excitation spectrum.

24,395 THE EFFECT OF NEODYMIUM ENVIRONMENT ON ITS ABSORPTION AND EMISSION CHARACTERISTICS IN GLASS by C. Hirayama and D.W. Lewis (Westinghouse); Phys. and Chem. of Glass, Vol. 5, pp. 44-51, Apr. 1964

The Nd^{3+} fluorescent decay time in alkali silicate glasses increases with increasing ionic radius of the alkali-metal modifier in the glass. Decay time also increases with increasing silica content until it reaches a saturation value of 1.03 ms at 85 mol per cent silica. The dependence of the fluorescence spectrum of the Nd^{3+} ion on its environment is shown.

24,396 FLUORESCENCE AND STIMULATED EMISSION FROM $Gd_2O_3:Nd^{3+}$ AT ROOM TEMPERATURE AND 77°K by B.H. Soffer and R.H. Hoskins (Korad); Appl. Phys. Lett., Vol. 4, pp. 113-114(L), Mar. 15, 1964

Fluorescence and stimulated emission from $Gd_2O_3:Nd^{3+}$ at room temperature and 77-K are discussed. The single crystals used in the measurements were grown by the flame fusion method, and had the monoclinic structure with lattice constants in good agreement with the results of Roth and Scheider. The fluorescence emission in the one micron region arises from the $^4F_{3/2}$ to $^4I_{11/2}$ transitions. The linewidths of the most intense lines are 20 to 30 cm^{-1} at room temperature and 8 cm^{-1} at 77°K. The fluorescence lifetime is ~120 μsec at room temperature and at 77°K. At room temperature the threshold for oscillation at 1.0789 μ was ~9 J, and at 1.0741 μ was about four times higher. At 77°K the threshold for the lines at 1.0789 μ and 1.0776 μ decreases in proportion to the linewidth narrowing. An unusually narrow output beam angle was observed.

24,397 FLUORESCENCE OF Cr^{3+} IN $LaAlO_3$ by R.C. Ohlmann (Westinghouse); Bull. Am. Phys. Soc., Vol. 9, p. 281(A), Mar. 1964

The fluorescence emission of chromium-doped lanthanum aluminate has been studied from 4.2°K to room temperature. The R-line emission is resolved into 2 lines at 4.2°K centered at 7335 and 7338 A. The 5.4 cm^{-1} splitting of these lines is caused by the spin-orbit interaction combined with the very small trigonal crystalline field. In the distorted perovskite structure of $LaAlO_3$, the rhombohedral cell angle is only 5' greater than 90°. At room temperature, these lines are unresolvable because of the 10-A width of the line. The satellite emission lines due to vibronically assisted transitions have been observed throughout the temperature range. The fluorescence decay time of the R lines is 76 msec at 4.2°K and it decreases to 46 msec at room temperature. These decay times are considerably longer than those recently published for this material. The fluorescence-excitation spectrum contains 2 broad bands in the visible centered at 5600 and 4125 A.

Fluorescence of Alkali Halides:Eu^{2+} - See 24,337

24,398 MÖSSBAUER EFFECT IN CHEMISTRY AND SOLID STATE PHYSICS by G.K. Wertheim (Bell Labs.); Science, Vol. 144, pp. 253-259, Apr. 17, 1964

The Mössbauer effect can be used very effectively by chemists and solid-state physicists. The author gives a qualitative explanation of this effect and discusses ways in which it has been used experimentally. It is discussed in terms of the isomer shift, electric hyperfine splitting, and magnetic hyperfine splitting in a more quantitative manner.

24,399 MÖSSBAUER EFFECT IN THE SYSTEM $SrFeO_{2.5-3.0}$ by P.K. Gallagher, J.B. MacChesney, and D.N.E. Buchanan (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 226(A), Mar. 1964

Mössbauer spectra were measured at 4°, 78°, and 300°K for the iron (III) and (IV) end members and two intermediate samples of the system $SrFeO_{2.5-3.0}$. At 300°K, the spectrum of $SrFeO_3$ [iron (IV)] consists of a single unsplit line having a half-width of 0.0441 cm/sec and an IS_{Cu} of -0.0171 cm/sec. At 4° and 78°K, the spectra consist of 6 lines with an IS_{Cu} of -0.0079 cm/sec and a hfs of 331 and 290 koe, respectively. As expected, no quadrupole splitting was observed in the cubic perovskite structure. The spectra of $SrFeO_{2.5}$ [iron (III)] are composed of two sets of 6-line spectra having IS_{Cu} of +0.0126 and -0.0047 cm/sec and hfs of 489 and 407 koe, respectively, at room temperature. Comparison with YIG predicted a crystal structure with equivalent amounts of octahedral and tetrahedral iron sites subsequently confirmed. There are quadrupole effects at the two sites that are of opposite sign.

24,400 MÖSSBAUER EFFECT FOR Fe^{57} IN BERYLLIUM, COPPER, TUNGSTEN, AND PLATINUM by J.P. Schiffer, P.N. Parks and J. Heberle (Argonne Lab.); Phys. Rev., Vol. 133A, pp. A1553-1557, Mar. 16, 1964

The Mössbauer effect has been studied for Fe^{57} as an impurity in Be, Cu, W, and Pt. The positions of the resonances and the ratios of recoilless fractions at different temperatures were determined. The behavior of these quantities as a function of temperature indicates the approximate correctness of the simple expectation that the impurity should behave as if it were in a solid composed only of the impurity atoms with a Debye temperature given by

$$\Theta_{eff} = (M_{host}/M_{impurity})^{1/2}\,\Theta_{host}.$$

Mössbauer Effect in Co- and Ni-Ferrite - See 24,261

24,401 LONG-WAVE EXCITATION OF THE BAND-EDGE LUMINESCENCE IN GaP CRYSTALS by E.F. Gross and D.S. Nedzvetskii (Acad. Sci. USSR); Soviet Phys.-Doklady, Vol. 8, pp. 989-992(L), Apr. 1964

The band-edge luminescence in GaP crystals excited by red light has been investigated. The long-wave maximum in the luminescence spectrum is more intense than the short-wave one in contrast to the case of excitation by blue light. The process of excitation can be explained in terms of a two-stage transition. It is however, shown that "red" excitation in the case of GaP crystals does not transfer electrons from the valence band into the conduction band and cannot be ascribed to the presence of copper impurity atoms. An attempt to discover the absorption bands responsible for the long-wave excitation is made. The result shows, however, that the absorption bands discovered do not seem to be associated with the "red" excitation of the band-edge luminescence.

24,402 LIFETIME OF THE EXCITED F_A CENTER IN ALKALI HALIDE CRYSTALS by G. Spinolo (U. Illinois); Bull. Am. Phys. Soc., Vol. 8, p. 241(A), Mar. 1964

Recent experimental results show that the radiative lifetime of the F center is as long as 0.58 μsec in KCl and 1.11 μsec in KBr. Similar pulsed luminescence and photoconductivity measurements were made on the F_A center, which is an F center with one of the nearest-neighbor potassium atoms replaced by a lighter alkali impurity such as sodium. In this case, the radiative lifetimes are somewhat shorter as follows: KCl-Na, $\tau_R = 0.54 \pm 0.01$ μsec; KBr-Na, $\tau_R = 1.0 \pm 0.1$ μsec. Although the F_A absorption band is double, only one emission band has been observed. A single radiative lifetime is found

24,403 LUMINESCENCE OF F' CENTERS IN KCl CRYSTALS by P.K. Gorbenko; Optics and Spectroscopy, Vol. 16, pp. 142-144, Feb. 1964

The results of an investigation of the luminescence of F' centers at low temperatures are presented. It was established that F' centers luminesce in the infrared region of the spectrum. A transfer (carry-over) of energy from excited F centers to F' centers when the energy is transferred occurs as a result of their thermal disintegration.

24,404 LUMINESCENCE OF MANGANESE-ACTIVATED MAGNESIUM GERMANATE by R.A. Phillips (U. Michigan); Rept. No. 2900 446R, Jan. 1964, 8 pp., Contract DA36 039sc78801; U.S. Gov. Res. Rep., Vol. 39, p. 122(A), Apr. 20, 1964 AD 428 536 OTS $1.10

The emission spectrum of $Mg_4GeO_6:Mn$ has been found to depend on the temperature of preparation. The spectrum of the sample prepared at 1275°C shows four narrow bands at 6200 A to 6600 A; the spectrum of the sample prepared at 1475°C consists of a broad band centered at 6150 A. X-ray diffraction patterns of the powders indicate the presence of an intermediate phase in the sample prepared at 127°C. It was concluded that the valence of the manganese activator is different in the two samples.

24,405 SOME RESULTS OF AN INVESTIGATION OF THE LUMINESCENCE OF POLARIZED ZnS:Cu:Cl LAYERS by Yu.S. Blank and I.I. Yatlinko; Soviet

Phys.-Solid State, Vol. 5, pp. 1963-1965, Mar. 1964

An investigation of the luminescence of polarized ZnS:Cu:Cl layers in a dc field is reported. In investigating the dependence of the spectral composition of the flash on the applied voltage, it is observed that the long wavelength part of the luminescence plays a relatively more important role and the spectrum is broadened. The dependence of the integral brightness on the pressure and composition of the ambient gaseous medium indicates the importance of the homocharge produced by the ionization.

24,406 LUMINESCENT PROPERTIES OF COPPER-ACTIVATED ZINC SULPHIDE IN THEIR DEPENDENCE ON THE ACTIVATOR CONCENTRATION by E. Ostaszewicz (Warsaw Tech. U.); Acta Phys. Polonica, Vol. 24, pp. 493-508, Oct. 1963

A satisfactorily simple and economical method of producing luminophors is described. A polarographic method is suggested for determining the copper content in the luminophors; the flame spectrophotometer was found to be inapplicable for this purpose. The spectral distribution of the fluorescence and electroluminescence intensities was investigated versus the copper concentration in the luminophors. The effect of copper concentration on: (a) the decay of the blue fluorescence band of zinc, (b) the crystallographical structure of the luminophors, and (c) the slight shift of the green fluorescence band towards shorter wavelengths has been clarified.

Luminescence of AgCl - See 24,338

PHOTOELECTRONIC PROPERTIES

24,407 PHOTOEFFECT IN A SUPERCONDUCTOR by V.V. Slezov; Soviet Phys.-Solid State, Vol. 5, pp. 2161-2165, Apr. 1964

The general formula describing the photocurrent as functions of frequency and temperature is derived. It is shown that the displacement of the red limit of the photoeffect is equal to the energy gap in the superconductor. The frequency dependence of the photocurrent in the vicinity of the new limit differs from the case of a normal metal as a result of redistribution of the electrons in momentum space.

24,408 PHOTOCONDUCTIVITY OF SULFUR SINGLE CRYSTALS AT HIGH HYDROSTATIC PRESSURES by N.A. Tokhomirova and V.M. Fridkin (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1980-1981(L), Mar. 1964

Measurement of the photoconductivity of sulfur single crystals in the pressure range between atmospheric and 10,000 atm. is reported. The data show that the pressure dependence of the photocurrent is superlinear and close to exponential. The observed photocurrent rise is due to an increase of the carrier lifetime, which results from the change of forbidden band width with the pressure.

24,409 SPECTRA AND KINETICS OF PHOTOCONDUCTIVITY RELATED TO SIMPLE STRUCTURAL DEFECTS IN GERMANIUM SINGLE CRYSTALS by I.P. Akimchenko, V.S. Vavilov and A.F. Plotnikov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1031-1035, Nov. 1963

A study of the spectra and kinetics of the photoconductivity related to deep levels of radiation defects produced by bombardment with 1 Mev electrons of pure and gold-doped germanium crystals is reported. It is found that the level detected at $E_v + 0.36$ ev relates to a vacancy, and the second deep level, $E_v + 0.42$ ev relates to an interstitial atom. The efficiency of the defect formation by fast electrons and the cross section for capture of holes are determined.

24,410 IMPURITY PHOTOCONDUCTIVITY IN GERMANIUM IRRADIATED BY HIGH-ENERGY ELECTRONS by R.Yu. Khansevarov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1976-1978(L), Mar. 1964

A study of the impurity photoconductivity in germanium irradiated by electrons with $E \cong 2$ Mev is reported. The spectral distribution of the impurity photoconductivity shows that the upper level lies at $E_c - 0.2$ ev and the kink in the curve at $\hbar\nu \cong 0.44$ ev points to the existence of a level located at $E_v + 0.25$ ev. Quenching was observed in all the irradiated samples investigated, and its characteristics can be interpreted in the same way as that observed in γ-irradiated germanium.

24,411 SATURATION PHOTOCONDUCTIVITY IN CdS SINGLE CRYSTALS [in German] by H. Kiess (RCA, Zurich); Phys. Status Solidi, Vol. 4, pp. 107-116, 1964

Saturation photoconductivity in CdS occurring at high field strengths and the dependence of this effect on the wavelengths and intensity of the incident light has been examined. Existing theories are found to be unable to explain the data obtained. A new saturation mechanism is advanced to account for the phenomenon.

24,412 A NEW MECHANISM FOR SATURATION OF PHOTOCURRENTS [in German] by H. Kiess (RCA, Zurich) and F. Stockmann (Tech. Hoch., Karlsruhe); Phys. Status Solidi, Vol. 4, pp. 117-124, 1964

A mechanism that accounts for the saturated photocurrent in single crystal CdS is described. It has been observed that the potential distribution has a limiting value of field strength at saturation that is not exceeded on further voltage increase. This fact is explained in terms of a field induced decrease in conductivity that is caused by field emission of minority carriers. An argument based on the thermodynamics of irreversible processes is cited to provide evidence for such an occurrence of a voltage region over which the current would remain constant.

24,413 PROPERTIES OF PHOTOCONDUCTIVE CdS EVAPORATED FILMS by Y. Sakai and H. Okimura (Tokyo Inst. Tech.); Japanese J. Appl. Phys., Vol. 3, pp. 144-149, Mar. 1964

Photoconductive CdS films were prepared by vacuum evaporation. Films evaporated on 200° - 300°C substrate achieve good photoconductivity by subsequent baking at a range of 500°C to 650°C in air or argon. Photocurrent-illumination characteristic, photoconductive time constant, spectral response, and temperature dependence of photocurrent were measured. Films of hexagonal structure were observed by X-ray diffraction. Photocurrent-illumination characteristic and photoconductive time constant of films are not inferior to those of a single crystal. The films show two types of typical spectral response; one is that of a single crystal and the other has a maximum peak in the vicinity of 580 mμ.

24,414 DEPENDENCE OF PHOTOCONDUCTIVITY GAIN ON PHOTON ENERGY IN CdS:I:Cu by R.H. Bube and B. Young (Stanford U.); J. Appl. Phys., Vol. 35, pp. 462-463(L), Feb. 1964

Evidence is presented in an attempt to prove that: (1) electrical and luminescent properties are due to the specific acceptor impurity; and (2) photosensitivity is due to other properties. Gain was found to decrease in the range where absorption by Cu impurities is dominant and to recover where absorption by defects is dominant. Photoconductivity gain vs photon energy is plotted.

24,415 INVESTIGATION OF PHOTOCONDUCTIVITY EXCITATION SPECTRA IN CdS AND CdSe CRYSTALS by F.I. Kreingol'd (Leningrad State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1769-1771, Mar. 1964

On the basis of an investigation of the excitation spectra of steady-state and transient photocurrents in CdS and CdSe at T = 66°K, the crystals are classified into three groups. It is shown that such a classification reflects the effect of recombination processes on the photoconductivity spectrum. The noncoincidence of spectral distribution of the steady-state and transient photocurrents in certain crystals is due to the long relaxation time of the photocurrent excited in the body of these crystals.

24,416 PHOTOELECTRONIC PROPERTIES OF IMPERFECTIONS IN CADMIUM SULFO-SELENIDE SOLID SOLUTIONS by R.H. Bube (Stanford U.); J. Appl. Phys., Vol. 35, pp. 586-596, Mar. 1964

The electron and/or hole ionization energy of imperfections in single crystals of cadmium sulfo-selenide solid solutions have been measured by a variety of photoelectronic techniques including optical absorption, optical quenching of photoconductivity, thermal quenching of photoconductivity, photoconductivity decay, and thermally stimulated conductivity. Both the optical and thermal hole ionization energy of sensitizing center acceptors undergo an abrupt decrease from a value characteristic of cadmium sulfide (~1 ev) to a value characteristic of cadmium selenide (~0.6 ev) between 30% and 50% cadmium selenide. The same transition is observed as an abrupt increase in the energy of the imperfection absorption edge, corresponding to the optical electron ionization energy of these centers. The electron ionization energy of electron traps varies approximately proportionally to the band gap throughout the solid solution range.

24,417 NATURE OF THE PHENOMENON INVOLVED IN THE GENERATION OF PHOTOCURRENT PULSES IN CADMIUM SELENIDE CRYSTALS by V.L. Vinetskii, I.D. Konozenko and S.I. Shakhovtsova (Acad. Sci. UkrSSR); Soviet Phys.-Solid State, Vol. 5, pp. 1971-1974, Mar. 1964

A model to explain the generation of periodic photocurrent pulses at low temperatures is proposed. It is assumed that trapping levels are filled by the action of light. When the electron concentration is increased sufficiently, an avalanche-type process is initiated, as a result of which electrons from the trapping levels are excited into the conduction band. This process leads to an exhaustion of the trapping levels after which the current falls again and the crystal cools off. Continued illumination leads to a repetition of the current peak.

24,418 KINETICS OF PHOTOCONDUCTIVITY IN p-TlSe SINGLE CRYSTALS by M.Kh. Alieva and G.A. Akhundov (Acad. Sci. Azerb. SSR); Soviet Phys.-Solid State, Vol. 5, pp. 1521-1523, Feb. 1964

Photoconductivity relaxation data in p-TlSe are presented. The temperature dependence of the time constant of the slow photoconductivity component shows the existence of trapping levels. The depth of the trapping level was found to be 0.15ev from the bottom of the conduction band. In the low temperature region, it is found that the trapping coefficient for electrons is 1.5×10^{-8} cm^3/sec and that for holes is 3×10^{-14} cm^3/sec.

24,419 PHOTOCONDUCTIVITY STRUCTURE IN CUBIC ZnSe by Y.S. Park (Aerospace Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 224(A), Mar. 1964

The photoconductive spectral-response curves of single crystals of cubic ZnSe exhibit the exciton structure as well as the impurity peaks at 77° and 4.2°K. The peak at 4384A observed at 4.2°K is attributed to the ground state of the exciton associated with the first valence band at k = 0. Using the exciton-binding energy of 0.020ev estimated by Aven et al., the excited states of the exciton peaks are identified by applying the hydrogenic-energy formula. The exciton-absorption lines correspond to the photocurrent maxima as in wurtzite compounds.

24,420 KINETICS OF IMPURITY PHOTOCONDUCTIVITY IN GaSe CRYSTALS by R.F. Mekhtiev, L.G. Paritskii and S.M. Ryvkin (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1198-1203, Dec. 1963

A significant photosensitivity in the impurity absorption region has been observed in GaSe crystals. The photosensitivity is associated with the presence of three types of "emitter" levels located at 0.4, 0.56 and 0.71 ev relative to the top of the valence band. The presence of multiple trapping levels is established. It is shown that if the emitter levels are nearly filled and the equilibrium conductivity is large, trapping does not affect the measured relaxation times.

24,421 PHOTOCONDUCTIVITY AND OPTICAL PROPERTIES OF SEMICONDUCTORS by H.Y. Fan (Purdue U.); Ann. Summary Rept., Nov. 15, 1963, 14 pp., Contract Nonr-1100(04); STAR, Vol. 2, p. 353(A), Feb. 8, 1964

Photoconductivity studies were made in n-type GaSb. Spectral response was measured in the temperature range 300°K to 77°K; some measurements were also made near liquid-helium temperature. The photoresponse extends beyond the intrinsic absorption edge, to photon energies about 0.1 ev smaller than the energy gap. The extension of the response was due to an impurity level 0.1 ev above the valence band. The impurity or lattice defect was introduced by tellurium or selenium which was used to compensate p-type material in order to obtain the n-type samples. Optical absorption of impurities in germanium was also studied. Chemical shift and chemical splitting of the ground state of the donor impurities were determined from measurements of the infrared excitation spectra of these impurities. The effect of strain on the absorption spectrum was investigated in order to study the symmetry of the energy states of acceptor impurities.

24,422 DIRECT TRANSITION AND EXCITON EFFECTS IN THE PHOTOCONDUCTIVITY OF GALLIUM PHOSPHIDE by D.F. Nelson, L.F. Johnson and M. Gershenzon (Bell Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 236(A), Mar. 1964

Photoconductivity spectra between 0.6 and 3.3 ev of vapor-grown, high- and low-resistivity GaP whiskers and of high-resistivity floating-zone-refined crystals of GaP were measured as a function of temperature. Structure seen in the spectra of high-resistivity whiskers and interpreted as direct exciton formation (with subsequent dissociation) permitted a determination of the energy gap at k = 0 and its temperature variation. It could be fitted by $E_G = 2.895 - 1.17 \times 10^{-6}\ T^2$ in ev for temperatures below 300°K. This structure is seen as a result of an anomalously large photoconductive response in the direct-transition region that was attributed to a mobility increase from optical excitation similar to that seen in InP, CdSe, and GaAs. In low-resistivity, sulfur-doped whiskers, photoconductivity arising from absorption in bound-exciton states associated with neutral sulfur donors was observed. The photoconductive lifetime at 296°K in high-resistivity whiskers was found to be 3×10^{-9} sec.

24,423 IMPURITY PHOTOCONDUCTIVITY AND SURFACE TRAPPING OF n-TYPE GaSb by M.A. Habegger and H.Y. Fan (Purdue U.); Bull. Am. Phys. Soc., Vol. 9, p. 237(A), Mar. 1964

The photoconductive response of n-type GaSb extends 0.1 ev below the intrinsic threshold. The extrinsic response arises from an impurity level at about 0.1 ev above the valence band, and observations indicate that this level is introduced by Te-doping. The intrinsic signal varies strongly in the temperature range 230° - 360°K, corresponding to an activation energy of 0.51 ev. Background light of a continuous spectrum quenches the signal by orders of magnitude. The signal dependence on the intensity of the background light varies with temperature and is consistent with the activation energy. The temperature dependence and quenching behavior are attributed to surface traps of minority carriers. Since the n-type material is known to have a p-type surface layer, the traps are electron traps located 0.51 ev below the conduction band. For etched surfaces, the trap density is of the order of 10^{12} cm^{-2}. For extrinsic excitation, the recombination proceeds via the valence band at temperatures above 200°K. At lower temperatures, the excited electron recombines directly with the impurity whose capture cross section is estimated to be 2×10^{-20} cm^2.

24,424 SENSITIZATION OF PHOTOCONDUCTION IN A ZINC OXIDE FILM BY EOSIN by S.J. Dudkowski and L.I. Grossweiner (Illinois Inst. Tech.); J. Optical Soc. Am., Vol. 54, pp. 486-491, Apr. 1964

The electrical conductivity in a zinc oxide thin film is increased by light absorption in an adjacent layer of eosin (Na). Activation spectra show that response is excited by irradiation in the eosin monomer and dimer absorption bands and in the long wavelength tail induced by the zinc oxide substrate. The photoresponse in bilayers varies with the one-half power of the illuminance, builds up and decays by first-order processes, and is proportional to the zinc oxide dark current. The temperature dependence approximately follows the zinc oxide dark conductivity. Measurements with voltaic couples show that charge transfer takes place across the interface. Possible mechanisms are discussed.

24,425 THE STRUCTURE OF THE ENERGY SPECTRUM OF CURPOUS OXIDE WITH TRANSITORY PHOTOCONDUCTIVITY by Yu.V. Vorob'ev and G.A. Kholodar' (Shevchenko State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1153-1157, Dec. 1963

The photoconductivity of cuprous oxide has been investigated in the region of 0.63, 0.8 and 2 μ, and the relaxation time τ of the photoconductivity has been measured at λ = 2 μ. It is found that the relaxation time in the region of the main maximum τ′ is always equal to τ, which contradicts the currently held ideas on the mechanism of the photoconductivity of Cu_2O, according to which τ′ should be much greater than τ. A new variant of the energy structure model is proposed, which has only one acceptor impurity level. It is shown that such a model can explain the results obtained here, as well as the experimental results obtained by other workers.

24,426 INTRINSIC PHOTOCONDUCTIVITY IN THE ALKALI HALIDES by G. R. Huggett (U. Rochester); July 1963, 108 pp., TN3, Grant DA ARO D31 124 679; U.S. Gov. Res. Rep., Vol. 39, p. 117(A), Apr. 20, 1964 AD 428 111 OTS $9.60

Photoconductivity in thin films of RbI, KBr, KCl and RbCl was measured at temperatures of 10° and 80°K. Photocurrents were stimulated by irradiating the sample in the fundamental absorption region with ultraviolet light. Saturation curves showing the dependence of photocurrent on the applied voltage were also obtained.

24,427 NONUNIFORM PHOTOCONDUCTIVITY IN ORGANIC SEMICONDUCTORS by A.I. Burshtein (Soans SSR); Soviet Phys.-Solid State, Vol. 5, pp. 922-931, Nov. 1963

The nonuniform steady-state photoconductivity is calculated on the basis of a two-exciton ionization mechanism. Diffusion of carriers and of all types of exciton is neglected. It is shown that changes in the field intensity and illumination create several situations in which it is possible to observe photoeffects with sharply different properties.

24,428 PHOTOCONDUCTION IN AZULENE by D.C. Hoesterey (Eastman Kodak); Bull. Am. Phys. Soc., Vol. 9, p. 265(A), Mar. 1964

The photoconductivity in melt-grown azulene crystals has been measured by the transient technique. Hole motion was observed, but the trapping lifetime was too short for a drift-mobility measurement. In the temperature range of -50° to 90°C, the electron mobility is constant at 0.15 cm^2/V·sec. This behavior suggests that there is only a small interaction between the electron and the intramolecular vibrations of the highly polar azulene molecule. The photoconductive excitation spectrum is similar to the luminescence excitation spectrum, beginning at 350 mμ - the second π-π* molecular transition.

Photoconductivity of:
CdS - See 24,064
Ge - See 23,929
Si - See 23,926

24,429 PHOTOMAGNETIC EFFECTS IN GERMANIUM IN STRONG MAGNETIC FIELDS by I.N. Nikolaev; Soviet Phys.-JETP, Vol. 18, pp. 1150-1151(L), Apr. 1964

Photomagnetic effects in germanium have been investigated in strong pulsed magnetic fields up to 150 koe. It is found that the odd photomagnetic EMF passes through a maximum at a certain value of the field, in agreement with the theoretical prediction of Kagan and Sobakin. On increase of the surface recombination velocity the maximum of the curve shifts toward weaker magnetic fields. The even photomagnetic EMF depends anomalously on the angle between the direction of the magnetic field and the normal to the illuminated surface of the sample, similar to that found by Kikoin and Lazarev in a field of

20 koe. The anomalous dependence of the effect on the angle appears even at room temperature when the sample is in a field of 150 koe.

24,430 PHOTOMAGNETIC EFFECT IN InSb AT LOW TEMPERATURES by D. N. Nasledov and Yu.G. Popov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2219-2220(L), Apr. 1964

Measurement of the photomagnetic effect in p- and n-type InSb single crystals containing various amounts of impurities between 77° and 6°K is reported. This result shows that up to 20°K the photomagnetic current increases with the magnetic field H and reaches saturation in strong fields, but at 6°K a decrease of the photomagnetic current with H is observed in strong fields. In weak fields (<100 oe), the photomagnetic current rises by a factor of 3-7 on cooling. At the lowest temperatures, saturation is observed. The surface recombination velocity estimated from the experimental data at 6°K is about 40 m/sec for p-type samples and 8 m/sec for n-type samples.

OTHER OPTICAL PROPERTIES

OPTICAL CONSTANTS

24,431 OPTICAL CONSTANTS OF PHOTOSENSITIVE LAYERS OF LEAD SULFIDE by N.A. Vlasenko and M.P. Lisitsa; Optics and Spectroscopy, Vol. 16, pp. 161-164, Feb. 1964

The optical constants of chemically produced PbS layers have been measured in the 0.8-4.0 μ spectral region. In the 1-4 μ interval, the index of refraction varies slightly, remaining several times less than the single crystal values. In the region $\lambda < 3\,\mu$, the absorption spectra of films and of single crystals are practically coincident, but in the longer-wavelength region the former have an added absorption which depends on the dimensions of the crystallites. The possible nature of the long-wavelength "plateau" of the fundamental absorption band and the added absorption observed in films is considered.

24,432 MEASUREMENT OF OPTICAL CONSTANTS AT HIGH TEMPERATURES by W.S. Martin, E.M. Duchane and H.H. Blau, Jr. (A.D. Little); Dec. 10, 1963, 26 pp., Contract AF19 604 7485; U.S. Gov. Res. Rep., Vol. 39, p.129 (A), Apr. 20, 1964 AD 428 932 OTS $3.60

A new method for accurately measuring the optical constants of metals at high temperatures is described. Data obtained using this method to study single crystals of tungsten, molybdenum and columbium are presented and discussed.

Optical Constants of Al and In Films - See 24,328

REFLECTIVITY (REFLECTANCE)

24,433 SPECULAR REFLECTION FROM A ROUGH SURFACE by A.S. Toporets; Optics and Spectroscopy, Vol. 16, pp. 54-58, Jan. 1964

The conditions for the appearance of a specular component in the reflection of a directional light beam from a rough surface are explained. The intensity of the specular component is found to depend quantitatively on the angle of incidence and the wavelength of the incident light and also on the average height of the micro-irregularities. The specular component of the reflected light is considered to be the result of the interference of light which has been diffracted by the micro-irregularities and which propagates in the direction of specular reflection.

24,434 INSTRUMENT FOR THE ABSOLUTE MEASUREMENT OF DIRECT SPECTRAL REFLECTANCES AT NORMAL INCIDENCE by J.E. Shaw and W.R. Blevin (Natl. Stand. Lab., Sydney, Austl.); J. Optical Soc. Am., Vol. 54, pp. 334-336, Mar. 1964

An accurate but simple reflectometer is described for measuring the spectral reflectances at normal incidence of flat, specularly reflecting surfaces. The instrument has a wavelength range of 0.2-2.5 μm and, with transparent samples, provides for simultaneous measurement of spectral transmittances.

Ultraviolet Reflection from Diamond - See 24,322

24,435 OPTICAL PROPERTIES AND BAND STRUCTURE OF GROUP IV-VI AND GROUP V MATERIALS by M. Cardona (RCA Lab.) and D.L. Greenaway (Lab. RCA, Zurich); Phys. Rev., Vol. 133A, pp. A1685-1697, Mar. 16, 1964

Room-temperature reflectivity measurements over the energy range 0.5 to 25 ev have been made on the lead salts PbS, PbSe, PbTe, and on SnTe and GeTe; reflection curves have also been obtained for the structurally closely related Group V semimetals As, Sb, and Bi. In addition, the lead salts were measured at 77°K in the region below 6 ev. Measurements of transmission, also in the energy range below 6 ev, both at room temperature and at 77°K were made on epitaxially-deposited thin films of the lead salts and of SnTe. The observed structure on the reflectivity and absorption curves could be analyzed in general terms by comparison with the results obtained for diamond and zincblende materials and in particular by comparison with a recent augmented plane-wave band structure calculation of one of the lead salts (PbTe). An analysis of the reflectivity curves for some of the materials studied, using the Kramers-Kronig relation, enabled a detailed comparison to be made of the optical constants obtained from both reflection and transmission results.

24,436 ANOMALIES IN THE REFLECTION SPECTRA OF CdSe SINGLE CRYSTALS by C.W. Litton, D.C. Reynolds and T.C. Collins (Aerospace Res. Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 224(A), Mar. 1964

Deflect-reflection peaks have been observed in CdSe prisms at 4.2°K. The wavelengths of these peaks depend upon the orientation of the wave vector of the light with respect to the crystalline c axis. Reflection spectra have been observed for both $k \parallel c$ and $k \perp c$. In every case, tungsten light was used and was polarized in the mode $E \perp c$. In the $k \parallel c$ direction, a reflection minimum, which appears at 6756 A for $k \perp c$, shifts to longer wavelengths by a few wavenumbers. Another peak is observed at shorter wavelengths which appears to be the same center associated with the 2nd valence band. This is not an excited exciton state and may be an electronic transition.

24,437 BAND STRUCTURE OF CdS — OPTICAL STUDY by W.C. Walker and J. Osantowski (U. California, Santa Barbara); Bull. Am. Phys. Soc., Vol. 9, p. 223(A), Mar. 1964

The reflection spectrum of cleaved single-crystal CdS in the region 4 to 28 ev has been studied. Reflection peaks associated with valence- to conduction-band transitions were observed at 5.6, 7.1, 7.9, 9.3, 9.7, 14.4, 16.1, and 17.4 ev. Transitions giving rise to this structure can be accounted for on the basis of structure in the density-of-states function recently deduced from photoemissive studies and are in semiquantitative agreement with the band calculations of Herman and Skillman. The peaks below 10 ev are found to originate on the same set of states arising from mixed crystal-field and spin-orbit multiplets about 1 ev below the valence-band edge and to terminate at three maxima in the conduction-band density of states. The 14.4, 16.1, and 17.4 ev peaks are then consistent with transitions from a single maximum in the valence-band density of states lying about 9.3 ev below the valence-band edge to the three conduction-band density-of-states maxima.

24,438 ULTRAVIOLET-REFLECTION SPECTRUM OF SEMICONDUCTORS WITH WURTZITE STRUCTURE by M. Cardona and G. Harbeke (RCA Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 223(A), Mar. 1964

The room-temperature reflection spectrum of hexagonal CdS and ZnS has been measured with linearly polarized light of wavelength longer than 1100 A. Measurements were taken with the electric field parallel and perpendicular to the c axis of the crystal. These spectra are very similar to the corresponding spectra of zincblende-type materials (the ZnS measurements are compared with measurements on cubic ZnS). The dependence of the spectra on the polarization direction of the radiation is small. However, polarization effects have been observed on the reflection peaks whose analog in zincblende materials is due to transitions at a point in the [111] direction of k space.

24,439 REFLECTIVITY OF SOLIDS IN THE VACUUM ULTRAVIOLET by J. Osantowski (California U., Santa Barbara); May 1963, 52 pp., NASA Grant NsG-91-60, NASA CR-53114; STAR, Vol. 2, p. 1046(A), Apr. 23, 1964 OTS $5.60 ph, $1.76 mf

Peaks observed in the reflection spectrum of several solids beyond the fundamental absorption edge have been attributed to direct interband transitions at symmetry points in the Brillouin zone. In this work, a special vacuum reflectometer was constructed, and the reflectivity of cubic single-crystal zinc sulphide was measured between 4 and 30 ev. Prominent reflectivity peaks were observed at 5.9, 7.2, 9.8, and 13.8 ev. The first three peaks were tentatively attributed to the $\Lambda_3 \rightarrow \Lambda_1$, $\Sigma_4 \rightarrow \Sigma_1$, and $L_3 \rightarrow L_{3'}$ transitions, respectively. This assignment was made by comparing the reflectivity of zinc sulphide with similar data and electron energy band calculations for germanium. The peak at 13.8 ev was attributed to a transition from the d-band, and this excitation energy was found to compare favorably with that obtained for zinc selenide.

24,440 INFRARED LATTICE SPECTRA OF NiO, CoO, AND MnO by R. Marshall, S.S. Mitra (IITRI), P.J. Geilisse and J.N. Plendl (AF Cambridge Res. Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 278(A), Mar. 1964

The room-temperature reflection spectra of NiO, CoO, and MnO and mixed NiO-CoO single crystals have been measured between 250 and 1600 cm^{-1}. Reststrahlen bands were observed at 473 and 365 cm^{-1}, respectively, for NiO and CoO. The high reflection in this region indicates strong ionicity, which is also confirmed by a calculation of Szigeti q^*, the effective ionic change. Subsidiary reflection maxima, probably arising through combination of the optical

acoustical phonons, were also observed. The gross features of the spectra ne mixed crystals revealed a continuous variation of positions and shapes of reststrahlen bands. Fine structure in the transmission spectra is attributed ne combination of the zone-boundary phonon frequencies.

441 TEMPERATURE STUDIES OF INFRARED REFLECTION SPECTRA OF $BaTiO_3$ AND $SrTiO_3$ IN THE 2-1000 μ REGION by V.N. Murzin and A.I. lieshina (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1716-7(L), Feb. 1964

nvestigation of the reflection spectra of polycrystalline $BaTiO_3$ and $SrTiO_3$ ne spectral region 2-1000 μ and in the temperature interval 45-140°C is re- ed. The reflection curves of both compounds have a broad plateau-like on at 22-1000 μ, and a maximum at 33 μ. No changes were found in the rection spectra of $SrTiO_3$ in the region 2-300 μ on varying the temperature ween 45 and 140°C. The temperature changes in the reflection spectrum of $BaTiO_3$ occur in the region of 55 μ and in the long-wavelength end of the spec- n.

442 ULTRAVIOLET REFLECTANCE SPECTRUM OF Al_2O_3, BeO, AND SiO_2 YSTALS by E. Loh (Hughes Res. Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 278 . Mar. 1964

t ultraviolet-reflectance spectra of flux-grown red ruby (Al_2O_3), flux-grown rillia (BeO), and natural quartz have been measured on natural faces of the tals. The measurements were made on a McPherson vacuum-ultraviolet spec- meter over the spectral range from 6 to 14 ev, at room temperature, and with ngle of incidence of 45 deg. The spectra show excitonlike peaks at 9.1, 4, and 10.4 ev for Al_2O_3, BeO, and SiO_2, respectively. The separation ween the exciton peak and the next-higher reflectance shoulder or peak is ut 1.4, 1.7, and 1.3 ev for sapphire, beryllia, and crystal quartz, respec- ly. The reflectance spectrum of sapphire resembles that of MgO except for niform shift by ~1.5 ev toward higher photon energy.

ectivity of:
HgTe and HgCdTe - See 24,334
Si - See 24,329

REFRACTION

443 DISPERSION OF THE INDEX OF REFRACTION NEAR THE ABSORP- N EDGE OF SEMICONDUCTORS by F. Stern (IBM Watson Res. Ctr.); s. Rev., Vol. 133A, pp. A1653-1664, Mar. 16, 1964

imple method is used to calculate the contribution of the rapid rise in opti- absorption near the absorption edge of semiconductors to the index of re- tion near the edge. Other contributions to the index are also estimated. results give qualitative agreement with the results obtained for PbS by dl and Schoolar, and very good agreement with Marple's prism measure- nts of the index for GaAs. Some applications to injection lasers are discuss- The temperature and pressure dependence of the index of refraction near absorption edge is estimated, and agrees well with experimental results for As.

444 REFRACTIVE INDEX OF GaAs by D.T.F. Marple (GE Res. Lab.); Appl. Phys., Vol. 35, pp. 1241-1242, Apr. 1964

asurements of the refractive index of GaAs by the prism refraction method reported for photon energies from 0.7 ev up to the absorption limit set by band gap, for temperatures of 300°, 187°, and 103°K. The results are com- ed with the previous data (obtained only for room temperature), and are d to show that the spacing of emission lines of GaAs lasers corresponds to t of the axial modes of a Fabry-Perot resonator.

445 REFRACTIVE INDEX OF ZnSe, ZnTe, AND CdTe by D.T.F. Marple E Res. Lab.); J. Appl. Phys., Vol. 35, pp. 539-542, Mar. 1964

fractive indexes of ZnSe, ZnTe, and CdTe obtained from prism refraction a are reported for a series of wavelengths from 2.5 μ to the short-wave trans- sion limits set by the band gaps. The results were fitted with the standard mula: $n^2 = A + [B\lambda^2/(\lambda^2 - c^2)]$ where n is the refractive index and λ is the velength in microns. For ZnSe the best values of the parameters are A = 00, B = 1.90, and $c^2 = 0.113$; for ZnTe, A = 4.27, B = 3.01, and c^2 = 142; and for CdTe, A = 5.68, B = 1.53, and $c^2 = 0.366$. Possible causes for e discrepancies between the present results and earlier data are discussed.

fractive Index of:
Al and In Films - See 24,328
$InAs_ySb_{1-y}$ Films - See 24,331

446 EFFECTIVE THICKNESS OF TWO BIREFRINGENT CRYSTALS FOR THE STUDY OF NATURAL BIREFRINGENCE by M. Ziauddin (Nizam Coll., Hyderabad, India) and T.S. Narasimhamurty (Osmania U., Hyderabad); Rev. Sci. Instr., Vol. 35, pp. 303-305, Mar. 1964

A new optical technique using a birefringent compensator has been developed to study the natural birefringence of calcite and ADP. Experimental results are compared with those obtained by the usual banded spectrum technique. Application of this method for very highly birefringent substances is indicated.

Quantum Theory of Voigt Effect - See 24,449

Measurement of Voigt Ellipticity - See 24,451

447 ELECTRO-OPTIC EFFECT IN OPTICALLY ACTIVE CRYSTALS by C.F. Buhrer, L. Ho, and J. Zucker (Genl. Tel. and Electronics); Appl. Optics, Vol. 3, pp. 517-522, Apr. 1964

The optical properties of an optically active electro-optic crystal are analyzed. The coexistence of optical rotation and electrically induced birefringence is shown to limit the performance of an electro-optic light modulator of the usual type. A more general design for a light modulator is described which permits compensation of the optical activity, thus removing this limiting effect. Experiments performed using crystals of sodium thioantimonate gave results consistent with the analysis.

448 LINEAR ELECTRO-OPTIC EFFECT IN CdS by D. Gainon (Clevite); J. Optical Soc. Am., Vol. 54, pp. 270-271(L), Feb. 1964

Electro-optic coefficients were studied in CdS. Due to symmetry, only three independent electro-optic coefficients exist: r_{13}, r_{33}, r_{51}. The magnitudes of $(r_{13}-r_{33})$ and r_{51} were measured at 25°C using 5890 Å light and dc electric fields; the signs of the coefficients were also determined. It was found that $|r_{13}-r_{33}| = 4\pm1 \times 10^{-2}$ m/v and $r_{51} = 3.7\pm0.5 \times 10^{-12}$ m/v.

Optical Modulation in $(NH_4)_2Cd_2(SO_4)_3$ and $(NH_4)_2Mn_2(SO_4)_3$ - See 24,453

POLARIZATION (FARADAY) EFFECTS

449 QUANTUM THEORY OF INTERBAND FARADAY AND VOIGT EFFECTS by J. Halpern (Lincoln Lab.), B. Lax, and Y. Nishina (Mag. Lab. MIT); Phys. Rev., Vol. 134A, pp. A140-152, Apr. 6, 1964

A quantum-mechanical analysis of the Faraday rotation and the Voigt effect has been carried out for both the oscillatory and long-wavelength regions. Expressions have been developed for these effects from the off-diagonal and diagonal components, respectively, of the conductivity tensor; the latter has been obtained in the form of the Kramers-Heisenberg dispersion relations through the use of first-order time-dependent perturbation theory. The results, which have been calculated for a simplified two-band model, are generalized to apply in the high-field case as well as the low-field limit. Through the introduction of a phenomenological relaxation time, τ, line shapes have been calculated for both the direct and indirect transition for the Faraday and Voigt effects. These have been obtained as a function of frequency for various values of magnetic field and relaxation times. The results obtained enable the evaluation of g factors from experimental line shapes.

450 FARADAY EFFECT IN SEMICONDUCTORS by I.M. Boswarva (AE Res. Estab., Harwell); 1963, 144 pp., AERE-R-4341; STAR, Vol. 2, p. 917(A), Apr. 8, 1964 HMSO: 18/-NET

The general macroscopic and quantum mechanical formulas necessary to calculate the Faraday rotation in semiconductors are reviewed. Dispersion relations between Faraday rotation and absorption coefficient are derived, and it is shown how these rotations can be used to introduce damping phenomenologically. The general formulas are then applied to calculate Faraday rotation caused by (1) allowed direct band-to-band transitions, (2) forbidden direct transitions, and (3) indirect phonon-assisted transitions between a pair of simple bands. The major part of the thesis is devoted to an analysis of the Faraday rotation due to direct allowed transitions near $\underset{\sim}{k} = 0$ in semiconductors whose valence-band structure can be represented by the Luttinger-Kohn model. Specific computations have been performed to find the interband Faraday rotation in Ge, GaAs, InSb, InAs, and GaSb using effective mass parameters and other band constants.

451 INFRARED FARADAY ROTATION IN SEMICONDUCTORS: DOUBLE BEAM PHASE-SENSITIVE METHOD FOR THE MEASUREMENT OF INFRARED FARADAY ROTATION, ELLIPTICITY AND VOIGT EFFECT by G. Pidgeon and S. Smith (U. Reading); Infrared Phys. Vol. 4, pp. 13-28, Mar. 1964

The development of a double beam phase sensitive method of measuring infrared Faraday rotation of the order of 0.01° is reported. Extension of the method to measurement of Voigt and Faraday ellipticity is discussed, and some results obtained by the use of these techniques on III-V semiconductors are presented. An

interpretation is given of the oscillatory interband Faraday rotation in InSb. The temperature dependence of free electron scattering time is deduced from combinations of Faraday rotation and ellipticity measurements on n-type InSb.

24,452 TEMPERATURE DEPENDENCE OF THE MAGNETO-OPTIC EFFECT AND RESONANCE PHENOMENA IN ORIENTED MnBi FILMS by D. Chen and Y. Gondo (Honeywell Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 1024-1025, Mar. 1964

Magneto-optic Kerr rotation and crystalline anisotropy have been studied in MnBi films from 300° to 84°K. As the temperature decreases from 300° to 84°K, the following experimental results are obtained: (1) the Kerr rotation decreases by a factor of 3/2 when the film is in the remanent state; (2) the Kerr rotation increases by a factor of 10 when the film is in the saturation state; (3) the resistivity decreases by a factor of 2; and (4) the reflected light intensity decreases by a factor of 6. The ferromagnetic resonance absorption at 9.02 Gc/sec has been observed in the temperature range between 170° and 84°K, with the direction of the external dc field both perpendicular and parallel to the c axis of the film. The anisotropy constant estimated from the FMR data decreases from 4.5×10^6 erg/cm^3 at 162°K to zero at 84°K. This temperature dependence is in good agreement with Guillaud's result calculated from magnetization measurements. The spectroscopic splitting factor g is estimated to be 2.1 at liquid-nitrogen temperature, which is smaller than the previously reported value.

OPTICAL MODULATION

24,453 ELECTRO-OPTIC EFFECT IN $(NH_4)_2Cd_2(SO_4)_3$ AND $(NH_4)_2Mn_2(SO_4)_3$ by C. Buhrer and L. Ho (Genl. Tel. and Electronics); Appl. Optics, Vol. 3, p. 314(L), Feb. 1964

Application of crystals of $(NH_4)_2Cd_2(SO_4)_3$ and $(NH_4)_2Mn_2(SO_4)_3$ to the electro-optical modulation of light has been investigated. The wavelengths of the incident light were 3650-7900 A, and the modulation consisted of a 3000 v pulse (960 cps) applied along the [111] direction. Modulation indices ranged from 0.20 at the higher frequencies and fell to 0.075-0.09 for the longest wavelengths. The temperature dependence was investigated for the cadmium compound. No measurable optical activity is exhibited, and the ease of preparation indicates potential use as modulating elements.

24,454 PHOTON-INDUCED FREE-CARRIER MODULATION OF INFRARED LIGHT IN GERMANIUM by R.M. Grant (U. Michigan); Rept. No. 4563 55T, Jan. 1964, 16 pp., Contract AF33 616 8365; U.S. Gov. Res. Rep., Vol. 39, p. 131(A), Apr. 20, 1964 AD 429 003 OTS $1.60

The theoretical framework necessary to explain the modulation of an infrared beam by photon-induced free-charge carriers is briefly reviewed. An experiment is described which demonstrates that variations in the density of free-charge carriers in germanium can modulate the intensity of an infrared beam transmitted by the germanium.

24,455 MODULATION OF INFRARED BY FREE CARRIER ABSORPTION by R. B. McQuistan and J.W. Schultz (Honeywell Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 1243-1248, Apr. 1964

The phenomenon of free carrier absorption in germanium has been utilized to modulate infrared radiation. Criteria are established which provide bases for judging and comparing modulator performance. By solving the small-signal continuity equation for the spatial and temporal distribution of excess holes, expressions are obtained which relate the modulator performance to the fundamental electro-optical properties of the modulator material. Modulators have been fabricated having modulation bandwidths in the range 10^5 to 10^6 cps. Experimentally determined modulator characteristics are compared with theoretical predictions.

Optical Properties of InSb Layers - See 24,034

THERMAL PROPERTIES

SPECIFIC HEAT

24,456 ANOMALOUS LOW TEMPERATURE PROPERTIES OF METALS: BEHAVIOR OF THE ELECTRONIC SPECIFIC HEAT by L. Gold (Ledgemont Lab.); Phys. Status Solidi, Vol. 4, pp. k57-60, 1964

The need for a revision in the theoretical understanding of the properties of metals at low temperature is pointed out. The basic conception of the correct procedure for calculating thermodynamic quantities in the region where the translational energy levels are comparable to or greater than the thermal energy of the system is discussed, taking the specific heat of the free electron gas as an example.

24,457 ANOMALOUS BEHAVIOR OF SPECIFIC HEAT OF CRYSTALS WITH HEAVY IMPURITY ATOMS by Yu. Kagan and Ya. Iosilevskii; Soviet Phys.-JETP, Vol. 18, pp. 562-564(L), Feb. 1964

The specific heat of a crystal containing a small number of heavy impurity atoms has been determined at various ranges of temperature. It is shown that the resonance character of the oscillation spectrum of the impurity atom brings about a noticeable increase in the specific heat at low temperatures.

24,458 DYNAMIC ADIABATIC CALORIMETER: AN IMPROVED CALORIMETRIC APPARATUS by C. Solomons and J.P. Cummings (Honeywell Res. Ctr.); Rev. Sci. Instr., Vol. 35, pp. 307-310, Mar. 1964

An apparatus and technique for the simple but rapid determination of specific and latent heat data are described. The apparatus records automatically the energy-temperature plot for the sample on a conventional EMF vs time strip-chart recorder; most of the components required are commercially available. The calorimetric assembly embodies the major advantages of adiabatic, heat-flow, differential-thermal-analysis, and thermal-analysis calorimeters. An accuracy of ± 2 per cent can be readily attained; with some care, errors can be reduced greatly in many cases.

Specific Heat of a Heisenberg Ferromagnet - See 24,138

24,459 TOYA'S ELECTRON-PHONON INTERACTION AND LATTICE VIBRATIONS OF POTASSIUM by R.S. Srivastava and B. Dayal (Banaras Hindu U.); Prog. of Theoret. Phys., Vol. 31, pp. 167-176, Feb. 1964

The specific heat and elastic constants of potassium has been calculated using Toya's formulation. To improve the agreement with experiment, the argument of Bardeen's function was multiplied by 1.07. Values of C_{11} and C_{12} are given as calculated by using 1.07 and by using 1.00 with the former showing much better agreement with experimentally measured values. Calculations of specific heat were made using Blackman's sampling over 125 points in the Brillouin zone. Calculated values of C_v are compared with experimental values from 4.0 to 36°K.

24,460 LOW-TEMPERATURE HEAT CAPACITIES OF POTASSIUM, RUBIDIUM AND CESIUM by W.H. Lien and N.E. Phillips (U. California, Berkeley); Phys. Rev., Vol. 133A, pp. A1370-1377, Mar. 2, 1964

The heat capacities of potassium, rubidium, and cesium have been measured between 0.2 and 4.2°K. The thermal effective mass ratios are 1.25, 12.6, and 1.43, respectively. For potassium and rubidium these quantities are in reasonable agreement with theoretical estimates of the effects of band structure, electron-electron interactions, and electron-phonon interaction. The trends of the calculated and measured values suggest that the energy-band calculations overestimate the distortion of the Fermi surface in cesium. For potassium the elastic constants are known and can be compared with the observed T^3 term in the lattice heat capacity. The agreement is within the expected experimental errors. The T^5 term, however, does not agree with calculations based on a model that includes only first- and second-neighbor interactions.

24,461 λ ANOMALY IN THE HEAT CAPACITY OF SOLID HYDROGEN AT SMALL MOLAR VOLUMES by G. Ahlers and W.H. Orttung (U. California); Phys. Rev., Vol. 133A, pp. A1642-1650, Mar. 16, 1964

An apparatus for determining the properties of solid hydrogen at volumes between 15 and 23 cc/mole is described. The results of measurements on the λ anomaly in the heat capacity of solid hydrogen containing large concentration of orthohydrogen are reported for molar volumes from 15.8 to 22.6 cc. The λ temperature was found to vary with intermolecular separation R as R^{-5}, with a small contribution from a higher exponent. This is in agreement with the expected relative contributions of electric quadrupole and valence interactions to the intermolecular potential. The relative contribution of the λ anomaly to the total anomalous entropy was estimated. The λ anomaly was found to have at least two distinct peaks.

24,462 ATOMIC HEAT OF CESIUM FROM 0.3° TO 2°K by B.D. Martin and C.V. Heer (Ohio State U.); Bull. Am. Phys. Soc. Am., Vol. 9, p. 250(A), Mar. 1964

The atomic heat of a 0.54-mole sample of cesium of 99.98% purity was measured between 0.3° and 2°K. The atomic heat in this region is given by $C = 6.29T + 29.0T^3 + \Delta(T)$ mJ per mole·deg. The linear electronic term corresponds to an effective-mass ratio of $m^*/m = 2.82$. This is considerably larger than the value suggested by Lien and Phillips, and is one of the largest ratios observed for a simple metal. The cubic term corresponds to a Debye Θ of 40.6° at 0°K. The functional dependence of the measured Δ(T) term causes the Debye Θ to decrease smoothly to a value of 37.9° at 1.6°K.

24,463 LOW-TEMPERATURE HEAT CAPACITIES OF GALLIUM, CADMIUM, AND COPPER by N.E. Phillips (U. California, Berkeley); Phys. Rev., Vol. 134A, pp. A385-391, Apr. 20, 1964

The heat capacities of gallium, cadmium, and copper have been measured from about 1 or 0.2°K to 4.2°K. The experimental data for copper suggest that the measurements are accurate to within 3 per cent at 0.1°K and to within 1 per cent at temperatures above 0.2°K. In the superconducting state both gallium and cadmium show the typical deviations from the BCS law of corresponding states. The nuclear quadrupole contribution to the heat capacity of gallium was observed in the normal state but not in the superconducting state. The absence of this contribution in the superconducting state can be used to set an approximate lower limit of 60 sec for the spin-lattice relaxation time at 0.25°K. For cadmium $\theta_S = 209 \pm 2.3$°K, in reasonable agreement with the value calculated from the elastic constants.

24,464 SPECIFIC HEAT OF 50-50 PER CENT (WT) LEAD-TIN SOLDER FROM 0.1 TO 300°K by W. Ziegler and J. Mullins (Georgia Inst. Tech.); Cryogenics, Vol. 4, pp. 39-40(L), Feb. 1964

The specific heat of 50-50 per cent (wt) Pb-Sn solder has been measured from 0.1-300°K. Seventy 2-inch samples of No. 10 gauge Pb-Sn solder wire were used. Measurements were made using a Leeds and Northrup resistance thermometer with an adiabatic shield, high vacuum calorimeter.

24,465 SPECIFIC HEAT OF NIOBIUM BETWEEN 0.4° AND 4.2°K by B.J.C. Van Der Hoeven, Jr. and P.H. Keesom (Purdue U.); Bull. Am. Phys. Soc., Vol. 9, p. 268(A), Mar. 1964

Theory predicts that the lattice specific heat of a superconductor should be the same in both the normal and superconducting states. The normal-state specific heat is a sum of an electronic γT and the lattice term C_{ln}. Since for sufficiently low temperatures the superconducting electronic contribution C_{es} becomes negligible, the total superconducting-state specific heat C_s is equal to the lattice contribution C_{ls}. So, for reduced temperatures above $T_c/T = 5$, one expects that $C_s = C_{ln}$. For niobium, Hirshfeld et al. found that the superconducting specific heat C_s was less than the normal lattice contribution C_{ln}. Recent conversations with Boorse encouraged independent measurements. The results are as follows: below 3.3°/K, the normal-state specific heat of niobium, measured in a magnetic field of 17 kg, can be represented by $C_n = 7.79T + 0.094T^3$ mJ/mole·deg. This corresponds to a value of the Debye parameter at 0°K, $\Theta(0)$, of 275°K. For reduced temperatures above $T_c/T = 5$, C_s is equal to C_{ln}, and, thus, the specific heat of niobium does not appear to be anomalous.

Debye Temperature of Nb - See 24,030

24,466 THE SPECIFIC HEAT OF PLUTONIUM AT HIGH TEMPERATURES by N.E. Kay and R.G. Loasby (A.W.R.E.); Phil. Mag., Vol. 9, pp. 37-49, Jan. 1964

Measurements of the specific heat of plutonium from room temperature to the melting point are described. The data are analyzed and an estimate is made of the electronic contribution to the specific heat term for the α, β, γ and δ-phases. This term is large for all of these phases, and shows reasonable agreement with that derived from susceptibility data.

24,467 HEAT CAPACITY STUDIES OF URANIUM AND URANIUM-FISSIUM ALLOYS by H. Savage and R.D. Seibel (Denver Res. Inst. and Argonne Lab.); Sept. 1963, 29 pp., Contract W-31-109-eng-38, ANL-6702; STAR, Vol. 2, No. 420(A), Feb. 23, 1964

The heat contents of high-purity uranium and uranium-fissium alloys containing 3, 5, and 8 w/o fissium were measured at temperatures from 0°C through their fusion temperatures. The total heat content above 0°C was determined by drop calorimetry and quantitative differential thermal analysis. The total heat content from 0°C to 1200°C was found to be 16.1±0.3, 16.3±0.6, 16.3±0.6, and 16.4±0.4 kcal per equivalent gram atom, for the 0, 3, 5, and 8 w/o fissium alloys, respectively. Curves of the heat content vs temperature are plotted for all the alloys and the high-purity uranium. Heats of transition and of fusion were determined. The directly measured value of 2.9±0.1 kcal/g-atom for the heat of fusion of uranium is consistent with that of the alloys.

24,468 THE ENTHALPY AND HEAT CAPACITY OF URANIUM MONOCARBIDE TO 1200°C by L.D. Harrington and G.H. Rowe (Pratt and Whitney); Jan. 8, 1964, 16 pp., Contract AT(30-1)-2789, PWAC-426; STAR, Vol. 2, No. 419(A), Feb. 23, 1964 TID-4500, OTS $0.50

The enthalpy (or heat content) of uranium monocarbide was measured in the range 0°C to 1204°C (32°F to 2200°F) using an ice calorimeter. Determinations were made from five elevated temperatures to 0°C. The accuracy of these measurements is estimated to be ± 4 per cent. The heat capacity (or specific heat) was calculated from these data. These measured values for enthalpy and calculated values for heat capacity are compared with values found in the literature. The measurements of the enthalpy of platinum-20 per cent rhodium from 0°C to 1538°C (32°F to 2800°F) are also presented.

24,469 SPECIFIC HEAT OF EuO by C.F. Guerci, V.L. Moruzzi and D.T. Teaney (IBM Watson Res. Ctr.); Bull. Am. Phys. Soc., Vol. 9, p. 225(A), Mar. 1964

The specific heat of a 35-g powder sample of EuO has been measured from 15° to 280°K. A large and sharply defined anomaly was found at 69.2±0.2°K, due to the onset of ferromagnetism. This value for the thermodynamic Curie temperature is to be compared with $T_c = 67$°K obtained by McGuire from magnetic measurements, with the value of $\theta = 77$°K reported in the original paper by Matthias et al., and with $T_c = 77$° used by Nereson et al. to fit neutron data. The EuO was prepared by reacting metallic europium with Eu_2O_3. A metalrich mixture of metal and oxide was pressed in the form of small cylinders that were wrapped in tantalum foil. The mixture was then reacted at ~1100° in a vacuum of 10^{-6} Torr and the excess metal was distilled off. The resulting EuO was single phase with respect to X-rays and had a saturation magnetization within 97 per cent of that expected for EuO.

Specific Heat of:
Cu (Impure), Cu-Co and Cu-Fe - See 24,123
Mn-Cu - See 24,246

Heat Capacity of Ag and Pb - See 23,866

Debye Temperature of ZrC, ZrN, TiC and TiN - See 24,493

24,470 HIGH-TEMPERATURE HEAT CONTENT OF TUNGSTEN CARBIDE AND HAFNIUM CARBIDE by L.S. Levinson (Los Alamos Lab.); J. Chem. Phys., Vol. 40, pp. 1437-1438, Mar. 1, 1964

The heat content of tungsten carbide has been measured between 1276° and 2642°K and that of hafnium carbide between 1286° and 2805°K using a drop calorimeter.

24,471 VIRTUAL MODE CONTRIBUTION TO SPECIFIC HEAT OF DILUTE Mg ALLOYS by G.W. Lehman, J.A. Cape, R.E. DeWames and D.H. Leslie (NA Aviation); Bull. Am. Phys. Soc., Vol. 9, p. 251(A), Mar. 1964

Theoretical calculations of the change in lattice-heat capacity Δc_L when a host atom of mass M_H is replaced by an atom of mass M_I have been made. In general, if c_L is the lattice-heat capacity of the host crystal, than $\Delta c_L/c_L \rightarrow 3\epsilon(n_I/2n_H)$ as $T \rightarrow 0$°K, where $1+\epsilon = M_I/M_H$, n_I and n_H are impurity and host concentrations, respectively. For Mg—1 at.% Pb, $\epsilon = 7.6$, $\Delta c_L/c_L = 0.1$ at T = 0°K; however, at T = 12°K, $\Delta c_L/c_L \approx 0.5$ (using an Al frequency spectrum suitably scaled to Mg). This enormous contribution is associated with a nearly triply degenerate virtual mode resonance whose frequency is $\omega \cong 0.2\ \omega_M$, where $\omega_M = 4.5 \times 10^{13}$ sec^{-1}, the maximum frequency for Mg. The half-width of this resonance is $\Delta\omega \cong 0.03\ \omega_M$. Measurements on the alloys Mg—1 at.% Pb and Mg—1 at. % Cd have been made, and $\Delta c_L/c_L$ derived from these data are in substantial agreement with theoretical predictions.

24,472 SPECIFIC HEAT OF AMMONIUM HYDROGEN SULFATE IN THE TEMPERATURE RANGE FROM -70 TO +14°C by B.A. Strukov and M.N. Danilycheva (Lomonosov Moscow State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1253-1255, Dec. 1963

Measurement of the temperature dependence of the specific heat of NH_4HSO_4 crystals is reported. It is shown that in the region of the ferroelectric phase transition of the second kind at -2.55°C the specific heat is anomalous, which is possibly due to the effect of polarization fluctuations.

24,473 SPECIFIC HEATS OF ANTIFERROMAGNET $XMnF_3$ COMPOUNDS by V.L. Moruzzi and D.T. Teaney (IBM Watson Res. Ctr.); Bull. Am. Phys. Soc., Vol. 9, p. 225(A), Mar. 1964

The specific heat of 5 powder samples of $XMnF_3$ compounds (Na, K, NH_4, Rb, Cs) has been measured in the range of 15° to 280°K. Sharply defined peaks allow specification of the Néel temperatures to within about 0.2°K. For pseudocubic $NaMnF_3$, $T_N = 66.3$°K, and no evidence was found for a higher-temperature transition that was originally reported. For $KMnF_3$, $T_N = 87.6$°K, with a hysteresis of about 0.3°K; a second small peak is also observed at 186°K, the temperature above which the lattice regains cubic symmetry. For NH_4MnF_3, $T_N = 75.1$°K; for cubic $RbMnF_3$, $T_N = 82 \pm 1$°K; and for hexagonal $CsMnF_3$, $T_N = 51.5$°K.

24,474 THE GRÜNEISEN APPROXIMATION IN THE EQUATION OF STATE FOR SOLIDS AND CALCULATION OF CERTAIN PROPERTIES OF IONIC CRYSTALS by V.V. Mitskevich (Kapsukas Vilno State U.); Soviet Phys.-Solid State, Vol. 5, pp. 1127-1132, Dec. 1963

Calculations of the thermal expansion coefficient, compressibility and specific heat of NaCl, KCl, KBr and CsBr crystals for low and high temperatures are reported. The calculations show that the Grüneisen constant for NaCl-type crystals decreases appreciably from room temperature to low temperatures and remains almost constant for CsBr crystals. Variation of the frequency spectrum of the lattice with crystal deformation and the usefulness of the Einstein model are discussed.

Grüneisen Constant of:
Cd and In - See 24,489
Cu and Ge - See 24,490

THERMAL CONDUCTIVITY

24,475 ATTENUATING WAVE ANALYSIS OF HEAT FLOW IN CRYSTAL LATTICES by L.M. Magid (MIT); Phys. Rev., Vol. 134A, pp. A163-172, Apr. 6, 1964

A direct approach to the detailed analysis of the thermal relaxation and conduction processes in crystal lattices in the classical-temperature range is presented in terms of the mechanical energy transported by attenuating lattice waves. A second-order classical perturbation procedure, formulated in terms of time- and space-dependent normal coordinates, is used to solve for the dynamics of a slightly imperfect, nonlinear general crystal lattice model under the influence of an applied temperature gradient. Only the use of a random-phase assumption for initial wave amplitudes at $t = 0$ and statistical averaging of the subsequent dynamical response are required for the direct determination of the accepted lattice relaxation times from the time dependence of the stored mechanical-energy density (for first- and second-order perturbation terms). In addition, the well-known anharmonic, mass-fluctuation, and force-fluctuation components of the high-temperature thermal conductivity are found directly from the steady-state mechanical-power density within the lattice. No use is made of the Boltzmann transport equation or standard phonon scattering theory, although the results obtained are wholly consistent with their use. Finally, a brief discussion is given on the extension of this attenuating-wave technique to the corresponding quantum treatment of low-temperature heat flow in crystal lattices.

Solution of the Thermal Diffusion Equation - See 23,725

24,476 THE THERMAL CONDUCTIVITY OF AGGREGATES OF SEVERAL PHASES, INCLUDING POROUS MATERIALS by A.D. Brailsford and K.G. Major (English Electric, Whetstone); Brit. J. Appl. Phys., Vol. 15, pp. 313-319, Mar. 1964

Expressions for the thermal conductivity of two-phase media are derived for various types of structure, and these are compared with the experimental results of Sugawara and Yoshizawa. The extension to the case of three phases is given. For porous media, such as sandstone, the structure plays a vital part in the determination of the thermal conductivity, and a model is proposed which allows this feature to be included and which provides a consistent explanation of experimental data.

24,477 THERMAL CONDUCTIVITY OF FERROMAGNETIC METALS by L.N. Petrova (Kirov Urals Polytech. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1223-1226, Dec. 1963

The thermal conductivity of ferromagnetic metals arising from the energy differences of electrons with opposite spins is calculated by the density matrix method. At temperatures above the Debye temperature, electron-phonon scattering is assumed to be the principal scattering mechanism. The temperature dependence calculated is in qualitative agreement with experiment and is close in order of magnitude to normal electronic thermal conductivity of nontransition metals.

24,478 VARIABLE-STATE METHODS OF MEASURING THE THERMAL PROPERTIES OF SOLIDS by T.Z. Harmathy (Natl. Res. Council, Canada); J. Appl. Phys., Vol. 35, pp. 1190-1200, Apr. 1964

Two variable-state methods have been developed which both offer the advantage of producing negligible thermal disturbance in a solid during measurement. The first is a curve-fitting method; it makes use of the fact that the initial temperature rise, due to a constant flux plane heat source, at points within a certain region of a finite solid is essentially the same as that in an infinite solid. Temperature records obtained from such points thus can be analyzed with the assumption of linear heat flow, and used for calculating all thermal properties of the solid. The second is a pulse method. If a hot or cold pulse is applied to a plane surface of a specimen, the rise or drop of temperature at some distance from the surface will pass through a maximum; from the time of the maximum the thermal diffusivity can be calculated. The main advantage of this method is the ease of specimen preparation.

Thermal:
Conductivity of Organic Semiconductors - See 23,938
Resistivity of Ru - See 23,967

24,479 LATTICE THERMAL CONDUCTIVITY OF Cu BETWEEN 0.3° AND 4°K by P. Lindenfeld, E.A. Lynton and D. McLachlan (Rutgers U.); Bull. Am. Phys. Soc., Vol. 9, p. 251(A), Mar. 1964

The lattice thermal conductivity has been measured between 0.3° and 4°K on annealed polycrystalline specimens of Cu-Ge alloys with residual resistivities between 10 and 22 $\mu\Omega \cdot cm$. The continued systematic variation of the conductivity with the electronic mean free path confirms that, in this temperature range, the phonon heat transport is primarily limited by interaction with the conduction electrons. Systematic deviations from the expected temperature dependence of the lattice conductivity show, however, the existence of additional scattering mechanisms. Results on cylindrical and foil specimens show a marked size effect at all temperatures up to 4°K. It appears that, throughout the temperature range of the measurements, there is appreciable phonon scattering both by the sample boundaries and by the crystal substructure.

Thermal Conductivity of InSb, GaAs, GaSb, CdTe and CdS - See 23,868

24,480 THERMAL CONDUCTIVITY OF LOW-TEMPERATURE ELECTRON-IRRADIATED GaAs by F.L. Vook (Sandia Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 289(A), Mar. 1964

Measurements of the change in thermal conductivity of high-purity single-crystal GaAs were made upon 2-Mev electron irradiation and annealing. The linear increase in the additive thermal resistivity near 50°K is $1/K - 1/K_0 = 3.15 \pm 0.2 \times 10^{-19}$ cm·deg/W per 2-Mev electron/cm^2. Estimates of the defect concentration (based upon the change in strain rate as a function of electron energy), together with the observed increase in thermal resistivity, yield $1/K - 1/K_0 = 9.4 \pm 1.0 \times 10^3 C$ cm·deg/W, where C is the fractional point-defect concentration. This result is intermediate between those predicted by the point-defect scattering theories of Klemens and Ziman. Annealing begins near 55°K and accelerates near 190°K. About 70 per cent of the additive thermal resistivity stable at 50°K anneals below 325°K. Definite minima are observed in the temperature dependence of the thermal conductivity, suggesting localized mode scattering. The change in shape of the temperature dependence of the thermal conductivity upon annealing indicates that below 325°K the defects anneal as point defects. For anneal temperatures between 325° and 575°K the point defects no longer remain isolated and clustering or precipitation is suggested.

24,481 THERMAL CONDUCTIVITY AND SEEBECK COEFFICIENT OF InP by I. Kudman and E.F. Steigmeier (RCA Labs.); Phys. Rev., Vol. 133A, pp. A1665-1667, Mar. 16, 1964

The thermal conductivity and the Seebeck coefficient of two undoped InP crystals were measured between 300° and 800°K. Computed values of the Seebeck coefficient, assuming pure polar scattering, are in excellent agreement with the experimental data. The electronic thermal conductivity was found to be negligible in InP. The interpretation of the lattice thermal resistivity provides strong evidence for the influence of optical mode scattering on the thermal resistivity of III-V compounds, which was postulated earlier by the authors.

Thermal Resistivity of PbTe and SnTe - See 23,832

24,482 THERMAL CONDUCTIVITY OF TITANIUM CARBIDE, ZIRCONIUM CARBIDE, AND TITANIUM NITRIDE AT HIGH TEMPERATURES by R. Taylor and J. Morreale (Atomics Intl.); J. Am. Ceramic Soc., Vol. 47, pp. 69-73, Feb. 21, 1964

The thermal conductivity of titanium carbide, zirconium carbide, and titanium nitride has been measured by a variety of techniques in the temperature range 200° to 2000°C. The titanium nitride results are a factor of four higher than previously published values at 1000°C and show a positive temperature coefficient for the thermal conductivity rather than the negative coefficient previously reported in other work. Recent thermal conductivity data on TiC confirm earlier data obtained by the writers. Contemporary theory fails to explain the temperature dependency of the phonon and/or electron contribution to the heat conduction in the refractory interstitial compounds.

24,483 THERMAL CONDUCTIVITY OF CHROMITE SPINELS by I.I. Vishnevskii, A.S. Frenkel' and V.N. Skripak (Ukrainian Sci. Res. Inst.); Soviet Phys. Solid State, Vol. 5, pp. 1966-1970, Mar. 1964

Measurements of the temperature dependence of the thermal conductivity of chromite spinels of various compositions are reported. It is shown that the thermal conductivity of an oxidized chromite spinel is substantially higher than that of the reduced form. The difference observed is accounted for by the effect of fourfold coordinated Fe^{2+} ions acting as phonon scattering centers. A discussion is given of the change in thermal conductivity as a function of solid-solution concentration in the high-concentration range.

24,484 THERMAL CONDUCTIVITY OF GRANULAR QUARTZ AT LOW TEMPERATURES by P.B. DeNee and R.B. Sawyer (Lehigh U.); Bull. Am. Phys. Soc. Vol. 9, p. 219(A), Mar. 1964

A nonsteady-state method, developed by Stalhane and Pyk, was used to measure the thermal conductivity of granular quartz from -200°-23°C. The thermal conductivity of the granular quartz at 1 atm of helium was found to increase

om 0.8 W/m°C at about -200°C to 1.1 W/m°C at 23°C and at a pressure of 10^{-4} Torr of helium was found to decrease from 0.1 W/m°C at about -200°C to 1.01 W/m°C at 23°C. There was no change in thermal conductivity with a change in particle size (0.5- to 0.3-mm particle diameter). These data were compared with the existing thermal-conductivity equations relating to granular material and found to agree best with the equation of Kunii and Smith.

4,485 THERMAL DIFFUSIVITY OF NON-METALLIC MATERIALS by B.S. Brinkworth (University Coll., Cardiff); Nature, Vol. 201, p. 1309, Mar. 28, 1964

Because of the comparative invariance of specific heat of insulating materials, the diffusivity is proportional to the ratio of conductivity to density. Although the conductivity of non-metallic materials decreases as the gross density decreases, their ratio is found to pass through a minimum, indicating that materials with lowest conductivities do not necessarily have low diffusivities. By plotting data from other experimentalists, a minimum in diffusivity was found to exist for non-metallic materials at a density of 1 g/cm^3. In materials with this density (such as polystyrene) the thermal diffusivity may be as low as 10^{-3} cm^2/sec.

THERMAL EXPANSION

Defect-Thermal Expansion Relationships - See 23,623

4,486 APPLICATION OF A VARIABLE TRANSFORMER TO THE STUDY OF LOW TEMPERATURE THERMAL EXPANSION by R.H. Carr and C.A. Swenson (Iowa State U.); Cryogenics, Vol. 4, pp. 76-82, Apr. 1964

The measurement of linear thermal expansions at low temperatures requires a sensor capable of detecting changes in the length of a sample with fractional Angstrom sensitivity (less than 10^{-8}). The present apparatus obtains this sensitivity through the change of mutual inductance as an astatic secondary coil of a variable transformer is moved with respect to a fixed primary coil. These coils and a sample chamber are immersed in liquid helium II in order to provide stability and to reduce noise. The present limitation in the sensitivity appears to be given by erratic drift in the zero mutual inductance of the coils, although the non-random noise is significant. Absolute thermal expansions are measured, and results have been obtained at temperatures down to 1.89°K for aluminum in various metallurgical states (single crystal, work hardened, annealed polycrystal), copper, and sapphire. The data for copper and aluminum agree with other published data, and in addition the aluminum data are found to be independent of the metallurgical state of the sample.

4,487 THERMAL EXPANSION AND MELTING ANOMALIES OF SMALL ALUMINUM CRYSTALS by Yu.I. Petrov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1793-1805, Mar. 1964

The thermal expansion of aerosol particles of aluminum of 2.5×10^{-6}, 4.6×10^{-6} and 3.5×10^{-5} cm diameter in vacuum and in argon has been studied by the X-ray diffraction method. An anomalously low expansion with a linear coefficient of 18×10^{-6} deg^{-1} was found for freshly prepared fine particles and for large particles after a preliminary heat treatment or long storage in dry air. The same particles exposed to an atmosphere with a relative humidity of 70-100 per cent or stored in water exhibited normal thermal expansion. The fine particles and the medium-sized "damp" particles exhibited, near the melting point, an anomalously sharp increase in the thermal expansion curves.

24,488 ON THE LOW TEMPERATURE THERMAL EXPANSION OF CERIUM by A.A. Gomes and A.M. de Graaf (U. Sao Paulo); Phys. Lett., Neth., Vol. 8, pp. 246-247(L), Feb. 15, 1964

A semi-quantitative description of the linear thermal expansion coefficient (α) of cerium as a function of temperature is given. Under the assumption that total entropy may be separated into a lattice contribution, a conduction electron contribution (which is small and can be neglected), and a magnetic contribution, $\beta/\chi = C_g\gamma_g/v + C_m\gamma_m/v$, where χ is the total compressibility, β is the volume thermal expansion coefficient ($\beta = 3\alpha$), C_g and C_m are the lattice specific heat and magnetic specific heat, respectively, and γ_g and γ_m are Grüneisen constants. Two mechanisms leading to a magnetic interaction between f electrons on different atoms were considered to determine γ_m. In one the f electrons occupy a bound state, in the other the f electrons occupy a virtual state. Only in the latter case was reasonable agreement found between the theoretical and experimental variation of α with temperature.

24,489 THE THERMAL EXPANSION OF Cd AND In by N. Madaiah and G. Graham (U. Toronto); Canadian J. Phys., Vol. 42, pp. 221-225(L), Jan. 1964

The linear coefficient of thermal expansion (α) of specimens of Cd and In have been measured in the temperature range from room temperature down to about 10°K by a dilatometric technique. Grüneisen's constant calculated from these results are reported to be constant at the values of 1.2 (Cd) and 2.5 (In) down to temperatures of the order of one-quarter of the Debye temperature.

24,490 THERMAL EXPANSION OF SOLIDS ON THE BASIS OF ANISOTROPIC CONTINUUM DISPERSIVE MODEL by K.C. Sharma and S.K. Joshi (Allahabad U., India); Phil. Mag., Vol. 9, pp. 507-512, Mar. 1964

The temperature variation of the Grüneisen parameter γ is calculated for copper and germanium on the basis of the anisotropic continuum dispersive model, from the observed elastic anharmonicity. The detailed nature of the frequency spectrum does not seem to have any pronounced effect on the thermal expansion of a solid.

24,491 THERMAL EXPANSION OF AlSb, GaSb, ZnTe AND HgTe AT LOW TEMPERATURES by S.I. Novikova and N. Kh. Abrikosov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1558-1559, Feb. 1964

A study of the thermal expansion of aluminum and gallium antimonides, and zinc and mercuric tellurides from 20° to 340°K is reported. It is found that the thermal expansion coefficient α becomes negative at low temperatures. The equation of state of solids is discussed for the case considered. It is shown that when α is negative, the interaction energy of atoms in a state of zero vibration must have a minimum with respect to the volume change.

Thermal Expansion of:
Al-Ag - See 23,625
FeS_2 and CoS_2 - See 23,606

24,492 THERMAL EXPANSION OF YTTRIA-STABILIZED ZIRCONIA by T. Nielsen and M. Leipold (Jet Propulsion Lab.); J. Am. Ceramic Soc., Vol. 47, p. 155(L), Mar. 21, 1964

The thermal expansion of yttria-stabilized zirconia has been measured in air and in a high oxygen atmosphere. The specimens of ZrO_2 and 15 wt. pct yttrium oxide had a single phase cubic structure as indicated by microstructure and X-ray analyses. The mean coefficient of thermal expansion of this material is presented for the temperature range 200°-2200°C. There was no significant difference in the thermal expansion measured in the two atmospheres.

24,493 THERMAL EXPANSION AND ATOMIC VIBRATION AMPLITUDES FOR TiC, TiN, ZrC, ZrN, AND PURE TUNGSTEN by C.R. Houska (Union Carbide Res. Inst.); J. Phys. Chem. Solids, Vol. 25, pp. 359-366, Apr. 1964

Pure tungsten and nearly stoichiometric ZrC, ZrN, TiC, and TiN have been investigated by X-ray diffraction. Thermal expansions and atomic vibration amplitudes have been measured, in some cases to above 2000°C. Although a different amplitude is possible for each atom type, a common isotropic amplitude is sufficient to fit the high temperature data, suggesting that equivalent forces act upon each atom within a given material. The vibration amplitude generally increased with thermal expansion, as expected. Compounds containing nitrogen and titanium exhibit larger amplitudes than those containing zirconium and carbon. Among the substances studied, tungsten has the smallest amplitudes and thermal expansions. Debye temperatures derived from the X-ray amplitudes decrease slightly with increasing specimen temperature.

24,494 THERMAL EXPANSION OF URANIUM MONOCARBIDE by R. Mendez-Penalosa and R. Taylor (Atomics Intl.); J. Am. Ceramic Soc., Vol. 47, pp. 101-102, Feb. 1964

The thermal expansion of arc-cast uranium carbide ranging from 4.35 to 5.05 wt. pct C has been measured from room temperature to 900°C for samples below 4.8 wt. pct C (U-UC mixtures) and to 2000°C for samples above this composition. Expansion of uranium carbide with compositions above and below the stoichiometric value was the same at low temperatures. For samples containing 4.7 to 5.05 wt. pct C, the linear thermal expansion can be expressed: pct expansion = $-0.0201 + 1.004 \times 10^{-3}\,T + 1.17 \times 10^{-7}\,T^2$, $20 < T < 2000$°C. The mean linear thermal expansion coefficient from room temperature up to 1000°C is 11.2×10^{-6}°C^{-1}; from room temperature up to 2000°C, it is 12.4×10^{-6}°C^{-1}.

THERMOELECTRIC AND THERMOMAGNETIC PROPERTIES

24,495 EFFECT OF PHONON DRAG ON THE LONGITUDINAL THERMAL EMF OF SEMICONDUCTORS AND SEMIMETALS IN A LONGITUDINAL MAGNETIC FIELD by P.S. Zyryanov (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1880-1882, Mar. 1964

The thermal EMF in the quantum limit is calculated both in the case of nondegenerate and degenerate electrons. The effect of phonon drag is considered. The expression for the thermal EMF in the case of zero magnetic field is given. If the phonon drag is neglected, the expression for thermal EMF for nondegenerate electrons and zero magnetic field transforms into the well-known classical result.

24,496 THERMAL EMF DUE TO ELECTRON-MAGNON SCATTERING IN FERROMAGNETIC METALS by L.E. Gurevich and G.M. Nedlin (Acad. Sci.

USSR); Soviet Phys.-JETP, Vol. 18, pp. 396-402, Feb. 1964

The thermal EMF of ferromagnetic metals at temperatures considerably above 1°K but much below the Curie point is considered for the case where electron scattering by spin waves and defects is important. It is shown that when scattering by defects predominates, a thermal EMF produced is inversely proportional to the defect concentration and can exceed the usual first-approximation thermal EMF.

24,497 THERMAL AND THERMOELECTRIC PROPERTIES OF FERROMAGNETIC METALS by A.I. Rezanov; Doklady Akad. Nauk SSSR (Moscow), Vol. 82, No. 6, pp. 885-887, 1952, NASA Contract NAS7-100; STAR, Vol. 2, p. 905(A), Apr. 8, 1964 NASA CR-53070; Int. Off. Mem. T-37, OTS $1.10 ph, $0.80 mf

By expressing the kinetic equation in the usual form and making use of the second approximation to calculate the integrals of antisymmetrical quantum statistics, as well as to calculate the dependence of the effective mass, chemical potential, energy, and mean-free-path traversal time of the outer electrons on the spontaneous magnetization, the equations for the Thomson coefficient and Peltier heat value were obtained. It was demonstrated from all of the derived equations that the temperature dependence of the ferromagnetic "perturbations" of the investigated variables is determined by the square of the spontaneous magnetization, whereas the temperature coefficients corresponding to each of these variables exhibit a strong maximum near the Curie point.

24,498 THERMOELECTRIC POWER OF NOBLE METALS by F.J. Blatt (ETH, Zurich); Phys. Lett., Neth., Vol. 8, pp. 235-237(L), Feb. 15, 1964

A mechanism that explains the positive absolute thermoelectric power of copper is discussed. It is shown that electron-electron scattering can lead to an effective relaxation time for the belly region of the Fermi surface which has the characteristics necessary for a positive absolute thermoelectric power. The proposed mechanism also explains the drastic reduction of the diffusion thermo power in copper caused by impurities. It is pointed out that electron-electron scattering should increase the Wiedemann-Franz ratio of copper at low temperatures.

24,499 THERMOELECTRIC POWER OF HOT CARRIERS by J. Zucker (Genl. Tel. and Electronics); J. Appl. Phys., Vol. 35, pp. 618-621, Mar. 1964

Measurements made at room temperature of the thermoelectric effect of hot carriers in n- and p-type germanium excited by the application of strong 2.85-Gc/sec microwave fields have been analyzed by applying the usual theory of thermoelectric power to the case of hot carriers. The carrier temperature T_e and the energy relaxation time τ_e have been calculated from the data. For the carrier temperature equal to the lattice temperature ($T_0 = 300°K$) the energy relaxation time for pure n-type germanium was 13.4×10^{-12} sec, while that for pure p-type germanium was 4.9×10^{-12} sec. In both cases τ_e fell with rising carrier temperature, to about 0.55×10^{-12} sec for the n-type germanium for $T_e > 3\,T_0$ and to about 0.4×10^{-12} sec for the p-type germanium sample at $T_e = 2.5\,T_0$. In both cases there were oscillations in the curves of energy relaxation time vs carrier temperature and ratio of energy relaxation time to momentum relaxation time vs carrier temperature. An explanation of this effect is based on energy loss via optical modes.

24,500 TEMPERATURE AND CONCENTRATION DEPENDENCE OF THERMAL EMF IN p-TYPE GERMANIUM by M.N. Vinogradova, O.A. Golikova, I.N. Dubrovskaya, and B.Ya. Moizhes (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1204-1211, Dec. 1963

Measurement of the thermal EMF in p-type germanium over the temperature interval 300°-950°K and concentration range 7×10^{17} to 7×10^{20} cm^{-3} is reported. The discrepancies between the theoretical and experimental values for $n > 10^{20}$ cm^{-3} and $T = 300°K$ and also for $T > 300°K$ for lower concentrations are explained by deviation from the quadratic dispersion law with increase in energy. This explanation is in agreement with the change in conductivity, Hall constant and thermal EMF in the region of almost intrinsic conduction.

Thermoelectric Power of:
Organic Semiconductors - See 23,938
$AuSb_2$ and Cu_2Sb - See 23,994
SnTe - See 23,833
$CrSi_2$ - See 23,993
NiO(Li) - See 23,941

Seebeck Coefficient of:
Bi_2Te_3 - See 24,052
InP - See 24,481
PbTe-SnTe - See 23,832
$SrTiO_3$ - See 23,992

24,501 ON THE THEORY OF THE NERNST-ETTINGSHAUSEN EFFECT IN FERROMAGNETIC METALS by E.I. Kondorskii (Moscow State U.); Soviet Phys.-JETP, Vol. 18, pp. 351-357, Feb. 1964

A theory of the Nernst-Ettingshausen (N-E) effect in ferromagnetic metals is presented, which can explain the temperature dependence of the N-E field observed experimentally and the change of sign of the N-E coefficient observed in iron on transition from low to high temperatures. Comparison of the theory with experiment shows that nonlocalized electrons make the principal contribution to the spontaneous magnetization of the iron and nickel.

24,502 DEGREE OF LOCALIZATION OF MAGNETIC ELECTRONS AND THE NERNST-ETTINGSHAUSEN EFFECT IN FERROMAGNETIC METALS by E.I. Kondorskii and R.P. Vasil'eva (Moscow State U.); Soviet Phys.-JETP, Vol. 18, pp. 277-278, Feb. 1964

An experimental study of the Nernst-Ettingshausen effect in ferromagnetic metals and some of their alloys is reported. The results obtained confirm the correctness of the theory developed by Kondorskii and lead to the conclusion that spontaneous magnetization carriers (magnetic electrons) in iron, nickel and cobalt take part in charge transport while in gadolinium they are bound to ions.

24,503 CALCULATION OF THE THERMOMAGNETIC COEFFICIENTS OF SEMICONDUCTORS by I.V. Dakhovskii (Chernov State U.); Soviet Phys.-Solid State, Vol. 5, pp. 2209-2211(L), Apr. 1964

Calculations of the dependence of the dimensionless transverse and longitudinal Nernst-Ettingshausen effects on the parameter $\mu H/c$ are presented. It is shown that the present method of evaluating the integrals encountered in the kinetic theory of semiconductors can simplify the calculations of the transport coefficients considerably.

24,504 NERNST-ETTINGSHAUSEN EFFECT IN STRONGLY DOPED n-TYPE Ge by L.I. Domanskaya, E.M. Omel'yanovskii, V.I. Fistul' and I.M. Tsidil'kovskii (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 2231-2233(L), Apr. 1964

The Nernst-Ettingshausen effect in n-type Ge doped with As with electron concentration n in the range $10^{16} - 4 \times 10^{19}$ cm^{-3} has been investigated in the temperature region 100°-300°K. The negative sign of the transverse N-E effect for all samples, except the one with lowest electron concentration (1.7×10^{16} cm^{-3}), indicates that impurity scattering predominates. At low values of n, comparison of theoretical calculations with experimental values shows that the electrons interact mainly with acoustical phonons.

24,505 MAGNETOTHERMAL OSCILLATIONS IN BISMUTH by B.D. McCombe and G. Seidel (Brown U.); Bull. Am. Phys. Soc., Vol. 9, p. 263(A), Mar. 1964

Magnetothermal oscillations, the de Haas-van Alphen type of oscillatory dependence of the temperature of a metal on the magnetic field, have been observed in bismuth in magnetic fields up to 24 kg, using an ac field modulation, phase-sensitive detection technique. Modulating fields both parallel and perpendicular to the linearly swept dc field have been employed. This procedure aids in the separation of the various periods of oscillation. Oscillations have been observed at 1.2° and at 0.35°K by using a ^3He cryostat. The signal-to-noise ratio is improved appreciably at the lower temperature.

MECHANICAL PROPERTIES

DEFORMATION PROPERTIES

24,506 MECHANICAL ENERGY FLOW IN CRYSTAL LATTICES by L.M. Magid (MIT); Phys. Rev., Vol. 134A, pp. A158-162, Apr. 6, 1964

A detailed study of the mechanical energy transported through a completely general crystal lattice in the classical temperature range is presented. Both a mechanical "Poynting" vector and the corresponding mechanical "Poynting" theorem are established for an arbitrary, 3-dimensional, anisotropic, anharmonic crystal lattice, containing many atoms per cell, inclusive of substitutional impurities, and possessing an arbitrary range of atomic interactions. The extension of the energy-flow procedures to a quantum treatment is discussed, a mechanical energy theorem, linking the average mechanical energy flow to the group velocity for the restricted case of a perfectly periodic and harmonic but otherwise completely general, crystal is derived for the classical temperature range.

24,507 INFLUENCE OF THE INTERNAL PHOTOEFFECT ON THE ATTENUATION OF ELASTIC WAVES IN Ge by V.M. Beilin, Yu.Kh. Vekilov, A.E. Kadyshevich, Yu.V. Piguzov and R. Rattke (Steel and Alloys Inst.); Soviet Phys.-Solid State, Vol. 5, p. 1726(L), Feb. 1964

An investigation of the attenuation of elastic waves in Ge by the "pulse echo" method at a frequency of 36 Mc and at room temperature during illumination of the sample is reported. At the beginning of illumination the attenuation in-

reases, while at the end, the attenuation recovers instantaneously to its ini- al value. The effect of illumination on the attenuation was found consider- bly weaker when the water filter was used.

4,508 DYNAMIC RESPONSE OF ALUMINUM by L.M. Barker and C.D. undergan (Sandia); J. Appl. Phys., Vol. 35, pp. 1203-1212, Apr. 1964

he dynamic stress-strain relation of aluminum has been measured in compres- on to a stress of 22 kbar using plate impacts to induce uniaxial strain. The re- lts were compared to a uniaxial strain curve constructed from elastic moduli nd quasistatically determined stress-strain curves. The dynamically determined ress-strain relation was not unique in that it varied as a function of the mag- itude of the induced stress and was offset from the quasistatic curve. These nall deviations are attributed to strain rate effects. The rate effects were fur- er demonstrated by observing the transmission of an elastic compression stress ave in aluminum after the aluminum was dynamically stressed beyond the yield oint and held at constant strain for a period of approximately 2 μsec. The dy- amic stress-strain relation was measured upon the release of a shock induced ompressive stress of 10.5 kbar to a tension of -9 kbar by observing the effects f tensile stress waves. The deviation of the unloading stress-strain relation from hat predicted by simple elastic-plastic theory is attributed to strain rate and auschinger effects.

4,509 CONTINUUM THEORY OF ASYMMETRIC ELASTICITY. (THE PROB- EM OF "INTERNAL" ROTATION) by R.V. Kuvshinskii and E.L. Aero (Acad. ci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1892-1897, Mar. 1964

. continuum theory of asymmetric elasticity taking into account the inherent r "internal" rotations of the particles in the medium is presented. All the quations of the new theory are given. The elastic potential, neglecting the iicromoment contribution, is of the same form as that in the Laval-Le Corre heory, which makes it possible to define the limits of applicability of the lassical elasticity theory.

4,510 THERMODYNAMIC DEFINITION OF HIGHER ORDER ELASTIC CO- FFICIENTS by K. Brugger (Bell Labs.); Phys. Rev., Vol. 133A, pp. A1611- 612, Mar. 16, 1964

eneral thermodynamic definitions of the higher order elastic coefficients of hermoelastic media are presented in tensor and engineering notation. They are atural generalizations of the customary definitions of second-order coefficients, hey retain the usual conventions relating tensor and engineering stresses and rains, and they simplify thermodynamic calculations.

4,511 THIRD-ORDER ELASTIC CONSTANTS AND THE VELOCITY OF SMALL MPLITUDE ELASTIC WAVES IN HOMOGENEOUSLY STRESSED MEDIA by R. N. Thurston and K. Brugger (Bell Labs.); Phys. Rev., Vol. 133A, pp. A1604- 612, Mar. 16, 1964

hird-order elastic constants can be determined from the velocity of small am- litude sound waves in statically stressed media. For this purpose exact expres- ions are derived for the sound velocity and for a natural velocity and their ress derivatives, evaluated at zero stress, in terms of second- and third-order lastic constants. The formulas apply to arbitrary crystal symmetry and to arbi- rary stress systems depending on a single scalar variable. Special formulas for ydrostatic pressure and uniaxial stress are listed for the cubic point groups O, Oh, Td, and for isotropic materials. Attention is given to the proper variation f propagation direction with static stress in order to maintain propagation nor- al to a given crystal face as in ultrasonic experiments, and to the proper sep- ration of isothermal and isentropic coefficients in the results. The simplest and ost convenient form of the results employs the natural velocity (natural un- tressed length at the same temperature divided by the transit time), which is omputed directly from experimental data without correcting the path length or the effect of stress.

4,512 THIRD-ORDER ELASTIC MODULI OF ANISOTROPIC SOLIDS by N. G. Einspruch and R.J. Manning (Texas Instr.); J. Appl. Phys., Vol. 35, pp. 60-567, Mar. 1964

inite elasticity theory is applied to the evaluation of the third-order elastic onstants of crystalline solids. Results are presented for cubic, hexagonal, etragonal, and orthorhombic symmetry.

4,513 TEMPERATURE DEPENDENCE OF ELASTIC CONSTANTS OF CENTRO- YMMETRIC CRYSTALS by V.V. Mitskevich (Kapsukas Vilno State U.); Soviet hys.-Solid State, Vol. 5, pp. 1133-1141, Dec. 1963

The elastic constants of crystals whose atoms are located on symmetry centers are determined by using the homogeneous static deformation method and taking nto account the crystal vibrations. Numerical calculations of temperature co- efficients of elastic constants at high temperatures are carried out for a number f alkali halide crystals. The results obtained are much closer to the experimen- al values than that obtained by Leibfried and Hahn.

24,514 THE MECHANICAL IMPULSE METHOD FOR DETERMINING DYNAM- IC ELASTIC MODULI AND INTERNAL FRICTION OF SOLIDS by H.F. Pollard; Australian J. Phys., Vol. 17, pp. 8-25, Mar. 1964

The theory governing the excitation of a linear mechanical system by a delta function impulse is summarized. In the case of a finite elastic rod excited by an impulse, the Fourier transform of the output function enables the frequency spectrum of the rod to be obtained. A spectrometer for accomplishing this operation is described and a comparative study is made between the impulse and resonance responses of a cylindrical rod. A discussion of the basic relationships involved in computing the dynamic elastic moduli and internal friction is presented, together with some typical data obtained by the mechanical impulse method.

24,515 PRESSURE DERIVATIVES OF THE SINGLE-CRYSTAL ELASTIC CON- STANTS OF POTASSIUM by P.A. Smith and C.S. Smith (Case Inst. Tech.); Bull. Am. Phys. Soc., Vol. 9, p. 238(A), Mar. 1964; Rept. No.7, Dec. 1963, 34 pp., Contract Nonr114105; U.S. Gov. Res. Rep., Vol. 39, p. 65(A), Apr. 5, 1964 AD 427 834 OTS $3.60

The elastic-stiffness constants of single-crystal potassium and their pressure derivatives have been measured at room temperature by the ultrasonic pulse-echo method. The values found in units of 10^{10} dyn·cm^{-2} are $C = C_{44} = 1.88$, $C' = (C_{11} - C_{12})/2 = 0.281$, $B_s = (C_{11} + C_{12})/3 = 3.34$, and $dC/dP = 1.62$, $dC'/dP = 0.251$, $dB_s/dP = 3.97$. The results have been interpreted in terms of Fuchs' theory of the electrostatic contribution to the shear stiffness of the alkali metals. The experimental observation that the elastic anisotropy C/C' does not depend on pressure indicates that, as Daniels found for sodium, it is not necessary to include an ion-core interaction or a Fermi contribution to the shear stiffness in order to account for the results. The latter conclusion is consistent with a spherical Fermi surface. The bulk modulus and its pressure dependence fit very well the simplest model of the binding energy.

Elastic Constants of K - See 24,459

24,516 YOUNG'S MODULUS OF SOME METALS AFTER DEFORMATION AT LOW TEMPERATURE AND ITS RECOVERY by W. Lems (Tech. Hog., Delft); Physica, Vol. 30, pp. 445-458, Mar. 1964

Measurements of the decrease of Young's modulus of Cu, Ag and Au, caused by small amounts of deformation at 78°K, are presented. The recovery process of this effect has been studied from 78°K to 350°K. The recovery procedure was effectuated under different circumstances, which allows a choice to be made between different recovery mechanisms and the type of point defects causing recovery.

24,517 ELASTIC CONSTANTS OF CsBr AND CsI FROM 4.2°K TO ROOM TEMPERATURE by J. Vallin, O. Beckman and K. Salama (Uppsala U., Sweden); J. Appl. Phys., Vol. 35, pp. 1222-1223, Apr. 1964

The elastic constants of pure single crystals of CsBr and CsI have been measured at liquid-helium, liquid-nitrogen, and room temperatures. For CsBr, the values of c_{11}, c_{12}, and c_{44} at 4.2°K are 3.437, 1.035, and 0.999 in units of 10^{10} N/m^2. The corresponding values of CsI at 4.2°K are 2.737, 0.793, and $0.825 \cdot 10^{10}$ N/m^2. The elastic constants give the Debye temperature 148.8°K for CsBr and 125.6°K for CsI. The infrared resonance frequencies calculated from compressibility data are in agreement with those obtained from infrared spectroscopy.

24,518 ELASTIC CONSTANTS OF Ni-Fe AND Ni-Cu ALLOYS by J. Sakurai, M. Fujii, J. Nakamura and H. Takaki (Kyoto U.); J. Phys. Soc. Japan, Vol. 19, pp. 308-310, Mar. 1964

The elastic constants of binary alloys, Ni-Fe and Ni-Cu, with wide composition ranges having fcc structure have been measured by means of a composite oscillator method in the frequency range from 1 to 5 Mc/s at room temperature. The elastic constants of Ni-Fe alloys vary quadratically with composition while those of Ni-Cu vary linearly. These results can be interpreted in terms of the central and pair-like interactions between atoms of the alloys.

24,519 THE ELASTIC PROPERTIES OF PYROXENES by K.S. Aleksandrov, T. V. Ryzhova and B.P. Belikov (Acad. Sci. USSR); Soviet Phys.-Cryst., Vol. 8, pp. 589-591, Mar.-Apr. 1964

Measurements of the elastic moduli of several monoclinic pyroxenes by the pulse method are reported. The constants are found to be related to the structure. Mean values are calculated for the Young's modulus and the shear modulus of monomineralic rocks; it is found that the mean values differ only a little for the various specimens investigated.

24,520 INFLUENCE OF TEMPERATURE, STRAIN RATE, SURFACE CONDI- TION, AND COMPOSITION ON THE PLASTICITY OF TRANSITION-METAL CARBIDE CRYSTALS by W.S. Williams (Union Carbide); J. Appl. Phys., Vol. 35, pp. 1329-1338, Apr. 1964

A fundamental study of the ductile-brittle behavior of the transition-metal monocarbides has been initiated through an investigation of the plastic deformation of single crystals of TiC, ZrC, and NbC. A vacuum furnace was used with an Instron testing machine for compression measurements in the temperature range 800° to 1600°C. The specimens were Linde single-crystal boules, cleaved into bars approximately 1 x 1 x 4 mm. The compressive stress was applied longitudinally in a <100> direction in the NaCl structure. The three carbides studied behaved similarly, but NbC was several times harder than TiC and ZrC. The critical resolved shear stress τ decreases exponentially with increasing temperature, increases approximately linearly with increasing carbon content, is little affected by surface condition, and increases as the logarithm of the strain rate. No yield point was observed. The effective stress exponent depends on the strain rate, ranging from 1 to 10. These results are discussed in relation to recent theories of the stress-strain relation.

24,521 PLASTIC DEFORMATION OF SOME PURE AND DOPED ALKALI HALIDES by W.G. Johnston (GE); Bull. Am. Phys. Soc., Vol. 9, p. 271(A), Mar. 1964

The plastic flow stress of "pure" alkali halide crystals exhibits a strong temperature dependence below room temperature, the flow stress at 20.5°K being roughly 25 times that at 300°K. NaCl crystals have been doped with Mn, Ca, or Sr in concentrations up to 1500 mole ppm. The flow stress of a "pure" crystal varies monotonically with temperature, but in lightly doped crystals with impurities in solution, there is a minimum in the flow stress below room temperature. At 20.5°K, the flow stress of NaCl varies as the square root of the impurity concentration, and the various impurities cause comparable hardening. The behavior of NaCl is compared with Mg-doped LiF, in which the hardness changes monotonically with temperature. The strain-aging, room-temperature aging, and strain-rate sensitivities of various alkali halides are compared. There is a particularly striking variation in the strain-rate sensitivity that is manifested in the yield-point behavior of the various materials.

24,522 THE PLASTIC DEFORMATION OF GERMANIUM SINGLE CRYSTALS: YIELD AND IDEAL EASY GLIDE by R.L. Bell and W. Bonfield (Imperial Coll., London); Phil. Mag., Vol. 9, pp. 9-36, Jan. 1964

Constant strain-rate tests were performed on very pure germanium single crystals oriented for easy glide. Studies of the effects of initial dislocation density, testing temperature and strain-rate lead to the conclusion that the yield point was due not to an impurity but to the multiplication of the originally small number of dislocations. Measurements of the strain-rate and temperature-dependence of the flow in a zero-hardening condition gave data on the velocity-stress relation for the dislocations. These enable a quantitative analysis of certain features of the yield point and a detailed investigation of the nature of the resistance to dislocation motion.

Plastic Deformation of Polymer Crystals - See 23,658

24,523 RADIATION-INDUCED STRESS RELAXATION IN QUARTZ AND VITREOUS SILICA by W. Primak (Argonne Lab.); J. Appl. Phys., Vol. 35, pp. 1342-1347, Apr. 1964

Helium or proton beams which penetrate several microns or more cause crazing on vitreous silica surfaces. In a lower energy range (beams up to 150 kev were used) there was observed upon irradiation a plastic flow stress relaxation that relieved the stress from the radiation-induced dilatation and resulted in the total volume change in vitreous silica or quartz occurring perpendicular to the surface. Implications of this radiation-induced stress relaxation seem fundamental to the radiation behavior of quartz, silica, and similar substances.

24,524 EFFECT OF ELECTRON IRRADIATION ON MECHANICAL PROPERTIES OF ALUMINUM SINGLE CRYSTALS AT 80°K by K. Ono, M. Meshii and J.W. Kauffman (Northwestern U.); Acta Met., Vol. 12, pp. 361-369, Apr. 1964

Aluminum single crystals of 99.999% initial purity were irradiated at 80°K with 1 Mev electrons to total dose of $1.2 \sim 8 \times 10^{17}$ el/cm^2. The flow stress was measured at 77°K over the strain rate range 5×10^{-4} to 4×10^{-3} and increased with irradiation. A larger increase for the higher strain rate was observed. The increase is interpreted to be due to interstitials which have migrated to dislocations and have been absorbed heterogeneously by making superjogs or kinks, which produce resistance to motion of the dislocations. An interruption of tensile test for a short time resulted in a yield drop which was found only in the irradiated crystals. This yield drop may be due to the Cottrell locking of the interstitials which were freed from impurity trapping sites by glide dislocations. Annealing at room temperature resulted in recovery of the hardening caused by the irradiation. Migration of vacancies or divacancies to the dislocation having interstitial jogs may produce the recovery.

24,525 PRESSURE DEPENDENCE OF CREEP IN WHITE PHOSPHORUS by K.L. DeVries, P. Gibbs, H. Miles and H.S. Staten (U. Utah); J. Appl. Phys., Vol. 35, p. 536, Mar. 1964

Bending creep in white phosphorus is reported at 27° and 41°C at pressures to 6 kbar. The activation volume for creep is approximately 50.3×10^{-24} cm^3/atom which is about the same as that determined by Nachtrieb and Lawson for self-diffusion.

24,526 THE TRANSITIONAL BEHAVIOR OF THE MINIMUM CREEP RATE OF β-COBALT by J.E. Flinn and E.R. Gilbert (Argonne Lab.); Phil. Mag., Vol. 9, pp. 557-564, Apr. 1964

Published data (Feltham and Myers 1963) on the second stage, minimum creep rate of β-cobalt have been analyzed for stress and temperature dependence. Three distinct stress functions and activation energies connected by regions of transition were found which behaved as parallel or additive processes over the temperature range of 450° to 750°C. The transition regions were found to have a stress and temperature dependence which could be empirically described.

Defect-Compressibility Relationships - See 23,623

24,527 THE COMPRESSION OF SOME RARE EARTH ELEMENTS by D.R. Stephens (Lawrence Radiation Lab.); J. Phys. Chem. Solids, Vol. 25, pp. 423-429, Apr. 1964

The compression ($\Delta V/V_0$) of Pr, Eu, Tb, Yb and Sc was measured to 45 kbars at room temperature. The phase transformation in Yb reported by several workers was determined to occur at 39.5±0.5 kbar with a volume change of 1.2± 0.1 per cent.

24,528 THE STRENGTH OF IRRADIATED MAGNESIUM OXIDE by R.A.J. Sambell and R. Bradley (AE Res. Estab., Harwell); Phil. Mag., Vol. 9, pp. 161-166, Jan. 1964

Magnesium oxide single crystals have been irradiated in a reactor to neutron doses in the range 2×10^{19} to 2×10^{20} n.v.t > 1 Mev. Any irradiation in this dose range prevents slip occurring below a stress of at least 1.3×10^2 kg mm^{-2} which was the maximum fracture stress observed (cf. 10 kg mm^{-2} as a typical flow stress before irradiation). The source of fracture is sometimes associated with pits produced by polishing and sometimes with impurity precipitates within the body of the crystal.

24,529 THE EFFECT OF ORIENTATION ON THE GRAIN SIZE DEPENDENCE OF THE YIELD STRENGTH OF METALS by E. Smith and P.J. Worthington (Central Electricity Res. Lab., Surrey); Phil. Mag., Vol. 9, pp. 211-216, Feb. 1964

A simple model is used to examine the effects of preferred orientation on the parameters σ_0 and k in the relationship $\sigma = \sigma_0 + kl^{1/2}$ relating the tensile yield stress σ of a polycrystalline aggregate to the grain diameter l.

24,530 FRACTURE STRENGTH OF MgO BICRYSTALS by R.C. Ku and T.L. Johnston (Ford Sci. Lab.); Phil. Mag., Vol. 9, pp. 231-247, Feb. 1964

The stress to form a crack, σ_F, at the tip of a glide band blocked by the grain boundary of a MgO bicrystal has been measured as a function of glide band length D. The relationship $\sigma_F = \sigma_0 + KD^{1/2}$ has been found to hold at room temperature in direct quantitative confirmation of Zener's model. The constant σ_0 is the stress for dislocation multiplication and K provides a qualitative measure of the effective cohesive strength at the glide band tip which in practice is dominated by porosity in the grain boundary. In addition, the effect of test temperature on σ_F, for a constant value of D, is described.

24,531 THE EFFECT OF HYDROSTATIC PRESSURE ON YIELDING IN IRON by F.P. Bullen, F. Henderson, M.M. Hutchison and H.L. Wain (Aeronautical Res. Lab., Melbourne, Austl.); Phil. Mag., Vol. 9, pp. 285-297, Feb. 1964

Armco iron normally shows a sharp yield point in tension at atmospheric temperature and pressure. This yield is either absent or substantially reduced in specimens subjected to hydrostatic pressures of 10^3-10^4 atmospheres prior to test. Removal of the yield point indicates that free dislocations are created during pressurization, apparently at elastic inhomogeneities such as inclusions. Evidence is presented to support this view, e.g. the fact that high-purity iron is not greatly affected by pressure. The observations are discussed in terms of recent theories of the influence of free dislocations on yielding.

24,532 RADIATION HARDENING IN ALKALI-HALIDE CRYSTALS by J.S. Nadeau (GE Res. Lab.); J. Appl. Phys., Vol. 35, pp. 1248-1255, Apr. 1964

Hardening by gamma irradiation has been investigated in eleven alkali halides with the rocksalt structure. The linear dependence of the flow stress upon the one-half power of the F-center concentration, as previously observed in LiF and KCl, was also observed in these new substances. (The earlier experiments showed that the hardening is not actually caused by F centers but by a defect resulting from F-center production). The rate of hardening with concentration was found in all cases to be consistent with that to be expected for nonsymmetrical defects. Comparisons were also made between the amount of hardening per defect and the lattice spaces available to certain specific defects. The only

ear correlation was with a halogen atom in the interstitial space at coordinates 0, ½, ½ in the unit cell.

4,533 STRAIN HARDENING IN POLYCRYSTALLINE COPPER by F.P. Bullen and C.B. Rogers (Aeronautical Res. Lab., Melbourne, Austl.); Phil. Mag., Vol. 9, pp. 401-412, Mar. 1964

Strain hardening in polycrystalline copper is shown to be the net result of two competing processes: (i) a basic process of strain hardening which occurs during deformation under a wide range of experimental conditions, and (ii) 'dynamic recovery' which removes a proportion of the obstacles produced during deformation. Arguments are presented which suggest that the basic process would give a linear rate of hardening but for an effect which occurs at high obstacle densities; this effect is also responsible for variation of the Cottrell-Stokes ratio at high degrees of hardening.

Work Hardening in Ge - See 23,685

SONIC AND ULTRASONIC PROPERTIES

4,534 ULTRASONIC PROPAGATION IN NICKEL AND Mn-FERRITE AT HIGH MAGNETIC FIELDS by J. Sakurai (Kyoto U.); J. Phys. Soc. Japan, Vol. 19, pp. 311-317, Mar. 1964

The velocity and attenuation of ultrasonic waves at magnetic fields, sufficiently high to produce magnetic saturation in nickel and Mn-ferrite, have been measured as a function of orientation, intensity of magnetic field, and ultrasonic frequency at room temperature. In the case of nickel, the change in ultrasonic velocity was inversely proportional to the applied magnetic field in the range from 5 to 20 kg; the ultrasonic attenuation coefficient also changed and showed a frequency dependence of the relaxation type $\omega/\omega_0/1+\omega^2/\omega_0^2$ in the range from 5 to 65 Mc. In the case of Mn-ferrite, it was found that the magnitude of the changes in ultrasonic velocity was almost the same as that in the case of nickel, but no attenuation change was observed within experimental error. All the observations can be explained by the theory based upon magneto-elastic coupling and eddy current loss.

4,535 OPTICALLY-INDUCED ULTRASONIC WAVES IN TRANSPARENT DIELECTRICS by A. DeMaria (United Aircraft Res. Labs.); Proc. IEEE, Vol. 52, pp. 96-97(L), Jan. 1964

Results of an experimental investigation of ultrasonic waves initiated in dielectrics by the passage of laser beams are discussed. Two hypotheses are postulated to account for the waves: (1) thermal expansion; (2) classical electromagnetic forces. Previous data favored thermal effects but the high optical E fields of laser beams preclude the discounting of electrostriction. Many dielectrics were used in the study; in particular, the results of using a 10-Mc $BaTiO_3$ transducer bonded to a glass block are cited. A 30 nsec laser pulse carrying 1 joule of energy was passed through the block. Correlation was noticed between observed pulses and the time required for 'echoing' of acoustic energy back and forth between the ends of the glass sample. Several control experiments were performed to preclude spurious effects such as thermal expansion of the ground electrode.

24,536 ULTRASONIC PROPAGATION IN SEMICONDUCTORS by V.I. Pustovoit (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1818-1825, Mar. 1964

The effect of ultrasonic amplification in piezoelectric semiconductors in the presence of carrier drift is discussed; and the effect of the magnetic field on the growth increment is investigated. It is found that the establishment of an unstable electron-hole plasma in a weak magnetic field in the case of an "immobile" lattice is not possible for any drift velocity.

24,537 EFFECT OF THE COULOMB INTERACTION ON ULTRASONIC ATTENUATION by Y. Osaka (Tohoku U.); J. Phys. Soc. Japan, Vol. 19, pp. 436-448, Apr. 1964

A calculation of the ultrasonic attenuation due to impurity scattering in a degenerate interacting electron gas is carried out. Contributions from diagrams of all possible combinations of the ladder interaction and exchange self-energy part are included. The result is essentially the same as those in the previous work, in which the Coulomb correlation was neglected.

24,538 RESONANCE DAMPING OF SOUND IN METALS IN A MAGNETIC FIELD by G. Akramov; Soviet Phys.-Solid State, Vol. 5, pp. 955-958, Nov. 1963

The resonance damping of the ultrasonic and spiral waves in metals placed in a magnetic field is analyzed. It is found that the damping of spiral waves decreases with increasing damping of the sound, and vice versa. In the case of strong coupling at the resonance point the damping of the sound and spiral waves is the same. The damping of the spiral waves was also found to increase with the decrease of the conductivity, in agreement with experimental observations.

24,539 THE ATTENUATION OF ULTRASOUND BY ELECTRONS IN ALUMINUM by B.K. Jones (U. Bristol, Canada); Phil. Mag., Vol. 9, pp. 217-230, Feb. 1964

The attenuation of transverse and longitudinal ultrasonic waves has been studied as a function of magnetic field strength in aluminum single crystals at liquid helium temperatures. The conventional magnetoacoustic configuration with $\mathbf{H} \perp \mathbf{q}$ and with longitudinal waves has been reported in some detail elsewhere. The effect with transverse waves in this configuration is shown here to be less pronounced. Most emphasis is given to the resonant interaction between the electrons and the sound wave observed for $\mathbf{H} \parallel \mathbf{q}$ when large peaks are observed in the attenuation. The theory is presented and reasonable quantitative agreement found with longitudinal waves. The rotation of the plane of polarization of the shear waves has been investigated and may explain the poor agreement for shear waves.

24,540 LOW-TEMPERATURE ULTRASONIC ATTENUATION IN CHROMIUM-GROUP TRANSITION METALS UP TO 1 kMc/sec by J.A. Rayne and C.K. Jones (Westinghouse); Bull. Am. Phys. Soc., Vol. 9, p. 250(A), Mar. 1964

Measurements of the low-temperature ultrasonic attenuation have been made as a function of crystallographic direction in tungsten and molybdenum. In all cases, samples having resistivity ratios of at least 5000 were employed, thus amply satisfying the condition $q l \gg 1$. For longitudinal waves, a linear dependence of electronic attenuation on frequency is observed up to at least 1 kMc/sec. The appreciable anisotropy in the electronic attenuation is discussed in terms of the Fermi-surface topology and deformation tensor for each metal.

24,541 INTERACTION OF TRANSVERSE ACOUSTIC WAVES WITH "NORMAL" ELECTRONS IN SUPERCONDUCTORS by J.R. Leibowitz (Westinghouse Res. Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 267(A), Mar. 1964

A simplified model was proposed in terms of which it is possible to obtain reasonable internal consistency among seemingly conflicting results obtained recently in experiments involving attenuation of transverse ultrasonic waves by "normal" electrons in superconductors. In treating the electron/shear-wave interaction in a superconductor, the model incorporates the collision-drag description for superconducting shear-wave attenuation, and includes shear deformation as well as electromagnetic interaction. It is concluded that the residual attenuation can be described by the relations $\alpha_R/\alpha_n = ag + D$ and $a + D = 1$, where a and D are independent of frequency. D represents the contribution associated with shear deformation of the Fermi surface under the stress of the injected lattice wave; α_n is the total (or normal state) electronic attenuation; α_R is the total residual attenuation; and g is incorporated directly from the collision-drag theory for superconducting attenuation. The model is examined in the light of recent results on Al, Sn, Ga, Nb, and V. From data on Al($q \parallel [110]$, $\epsilon \parallel [100]$), it is found that $D \approx 0.1$.

24,542 OSCILLATIONS IN ULTRASONIC ATTENUATION BY SUPERCONDUCTING TIN by L.T. Claiborne and N.G. Einspruch (Texas Instr.); Phys. Lett., Neth., Vol. 8, pp. 160-162(L), Feb. 1, 1964

Oscillations in the temperature dependence of ultrasonic attenuation in superconducting tin are discussed. The measurements were made using the pulse echo technique at 3 Mc in a 99.9999% pure, annealed Sn polycrystal. The absorption structure changed as the sample thickness was varied. Comparison of the theoretical constants for a model in which the frequency of the absorption maximum depends on the size of the superconducting phase with experimental constants indicates that the structure changes result from the size effect. "Wiggles" observed in the temperature dependence of the compressional wave attenuation in Ta can also be explained by a size effect.

24,543 DISPERSION RELATION FOR SECOND SOUND IN SOLIDS by R.A. Guyer and J.A. Krumhansl (Cornell U.); Phys. Rev., Vol. 133A. pp. A1411-1417, Mar. 2, 1964

The dispersion relation for second sound in solids is derived. The starting point of the analysis is a Boltzmann equation for a phonon gas undergoing a temperature perturbation $\delta T_0 e^{i(k\cdot x-\omega t)}$; the Callaway approximation to the collision term is employed. A dispersion relation which explicitly exhibits the need for a "window" in the relaxation time spectrum is obtained. Further, the dispersion relation shows that measurement of the attenuation of second sound as a function of frequency is a direct measurement of the normal process and umklapp process relaxation times. Macroscopic equations for energy density and energy flux are derived and their relation to the macroscopic equations with which Chester has treated second sound is shown.

24,544 GIANT QUANTUM OSCILLATIONS IN THE ULTRASONIC ABSORPTION IN GALLIUM by Y. Shapira (Natl. Magnet Lab., MIT); Bull. Am. Phys. Soc., Vol. 9, p. 239(A), Mar. 1964

Giant quantum oscillations in ultrasonic absorption have been predicted by Gurevich et al. Sharp spikelike "oscillations" in the absorption of 9- to 50-Mc/sec longitudinal sound waves propagated along the b axis in gallium in a parallel magnetic field up to 90 kg have been observed. At 1.7°K, the amplitude of the peaks at the highest frequencies and magnetic field used is ~10 dB/cm. The width of the absorption peaks and the magnetic field and temperature dependence of the amplitude of the peaks are in a fair agreement with predictions based on the theory of Gurevich et al. Some absorption peaks, however, show asymmetry that is not accounted for by the theory. In addition, the following new periods were found in gallium: 15×10^{-7} G^{-1} for H along the b axis, 12 and 1.2×10^{-7} G^{-1} for H along the c axis.

24,545 NONRESONANCE PARAMAGNETIC ABSORPTION OF SOUND DUE TO SPIN-LATTICE RELAXATION by V.A. Golenishchev-Kutuzov and E.G. Kharakhash'yan (Acad. Sci. USSR); Soviet Phys.-Solid State, Vol. 5, pp. 1992-1993(L), Mar. 1964

Observation of the nonresonance absorption of sound due to spin-lattice relaxation in copper sulfate is reported. The absorption coefficient changes markedly when the frequency or the temperature is changed. The dependence of the absorption on the constant magnetic field may be explained by a predominating spin-lattice interaction. The decrease in the absorption is related to the increase in the spin-lattice relaxation time.

24,546 SECOND-SOUND PROPAGATION IN DIELECTRIC SOLIDS by E.W. Prohofsky and J.A. Krumhansl (Cornell U.); Phys. Rev., Vol. 133A, pp. A1403-1410, Mar. 2, 1964

The conditions necessary for the occurrence of second sound in solids are examined in some generality. The results indicate that second sound can propagate at frequencies greater than the reciprocal umklapp relaxation time and smaller than the reciprocal normal relaxation time. At frequencies less than the reciprocal umklapp relaxation time, the solutions are the same as those for normal thermal conductivity. The frequency range and damping of second sound at various temperatures is computed using relaxation times determined for sodium fluoride.

Velocity of Acoustic Waves - See 24,511

24,547 EFFECT OF AN EXTERNAL ELECTRIC FIELD ON THE VELOCITY OF SOUND IN SEMICONDUCTORS AND SEMIMETALS by H.N. Spector (IIT Res. Inst.); Phys. Rev., Vol. 134A, pp. A507-511, Apr. 20, 1964

The effect of a dc electric field on the velocity of sound in semiconductors and semimetals has been studied. It is shown that the velocity of sound as a function of a dc field has either a maximum or minimum value at fields such that $V_d = S$. The particular cases studied are for acoustic waves propagating in an extrinsic semiconductor in a dc electric field and in a semimetal in crossed dc electric and magnetic fields.

24,548 DEPENDENCE OF THE ULTRASONIC WAVE VELOCITY ON TEMPERATURE IN SINGLE CRYSTALS OF PbS IN THE RANGE 80-640°K by A.A. Chudinov (Taganrogskii Pedagog. Inst.); Soviet Phys.-Solid State, Vol. 5, pp. 1061-1062, Nov. 1963

The propagation velocity of ultrasound in lead sulfide along the crystallographic directions [100] and [011] has been measured by the duplex oscillator method. The dependence of the velocity on the temperature was examined. With increasing temperature, the velocity of sound decreases according to a linear law. The compliance constants at room temperature have been calculated.

24,549 THE COUPLED MODES OF ACOUSTIC WAVES AND DRIFTING CARRIERS IN PIEZOELECTRIC CRYSTALS by K. Blotekjaer and C.F. Quate; Proc. IEEE, Vol. 52, pp. 360-377, Apr. 1964

The amplification of acoustic waves in piezoelectric semiconductors is analyzed in terms of the normal modes of the uncoupled system. The characteristics of the growing wave are presented for a range of the crystal parameters in terms of the conduction frequency (σ/ϵ) and the diffusion frequency (ν^2/D). Boundary conditions are worked out to show that an acoustic wave at the input to the amplifying section will couple into the growing wave without appreciable initial loss. The experimental results with CdS at 500 Mc confirm the general features of the theory and serve to point out two problems which must be overcome. The first is one of coupling into the acoustic waves from an external source. Present methods are quite inefficient. The second is one of internal oscillations within the crystal which occur when the drift velocity exceeds the velocity of sound. If these problems can be solved, it should be possible to use this gain mechanism well into the microwave region.

24,550 ACOUSTIC EMISSION UNDER APPLIED STRESS by B.H. Schofield (Lessells and Asso.); Apr. 1963, 17 pp., Contract AF33 657 8562; U.S. Gov. Res. Rep., Vol. 39, pp. 43-44(A), Mar. 5, 1964 AD 419 177 OTS $2.60

The role of the surface oxide layer in the generation of acoustic pulses in metals, i.e., acoustic emission, is discussed. Experiments were conducted on single crystals of aluminum of different crystallographic orientation. The specimens were pulled in tension both in atmosphere and exposed to etchant solutions. Results demonstrated the oxide layer is not itself an emission source and that the emission characteristics are significantly modified as a result of the influence of the oxide on the deformation behavior of the specimens. Specific observations suggest the operative mechanism of emission generation and the importance of the role played by the surface condition in the deformation of metals.

INTERNAL FRICTION

Calculation of Internal Friction - See 24,514

Internal Friction-Plastic Deformation Relationships - See 23,647

24,551 DISLOCATION RELAXATION PEAKS IN FCC METALS AFTER DEFORMATION AT 4.2°K by S. Okuda (Rice U.); Sci. Papers of the Inst. of Phys. and Chem. Res. (Tokyo), Vol. 57, No. 3, pp. 116-134, Sept. 1963, NASA Grant NsG-6-59; STAR, Vol. 2, p. 352(A), Feb. 8, 1964

The internal friction and dynamic modulus of gold, copper, silver and platinum have been measured in the temperature range from 4.2° to 300°K after deformation at 4.2°K and subsequent low-temperature annealing. The Niblett-Wilks and Bordoni peaks observed on gold and copper immediately after deformation at 4.2°K show a pronounced reduction in height after annealing around 180°K. These peaks regrow on room-temperature annealing. A detailed study is made on gold during low-temperature annealing. The Bordoni peaks in silver and platinum behave somewhat differently from those in gold and copper. These results are discussed in relation with the so-called annealing stages observed after irradiation or cold work.

24,552 INTERNAL FRICTION PEAK IN QUENCHED GOLD by S. Okuda (Inst. Phys. Chem. Res., Tokyo) and R.R. Hasiguti (U. Tokyo); J. Phys. Soc. Japan, Vol. 19, pp. 242-243(L), Feb. 1964

Internal friction studies of the relaxation peak appearing at -50°C in specimens of gold quenched from 1000°C are reported. This unstable peak is thought to be due to the stress induced reorientation of divacancies. Another peak observed around -60°C is thought to be due to dislocation-point defect interaction.

24,553 LOW TEMPERATURE INTERNAL-FRICTION HILL IN PURE, DEFORMED NIOBIUM by J. Schultz and R.H. Chambers (Genl. Dynamics/Genl. Atomic); Bull. Am. Phys. Soc., Vol. 9, p. 214(A), Mar. 1964

A low temperature maximum in the niobium-friction spectrum has been found below the previously reported a peak. The low-amplitude internal friction rises from $\approx 2 \times 10^{-5}$ at 50°K to a broad hilltop $Q_{max}^{-1} = 5.5 \times 10^{-5}$ extending from $\simeq$19° to ~11°K and then descends to $\sim 2 \times 10^{-5}$ at 2.5°K. Measurements were made at the longitudinal resonance at a frequency of ~8.8 kc/sec and at a strain amplitude of $\epsilon \sim 7 \times 10^{-9}$ on a pure ($\Gamma \sim 500$) niobium specimen deformed 10 per cent in torsion at room temperature which has an α-peak maximum Q_{max}^{-1} (188°K 8.8 kc/sec) $\sim 450 \times 10^{-5}$. Oscillation of the specimen at high amplitude at a temperature below the hill (~3°K) produced amplitude-dependent internal friction rising to approximately 35×10^{-5} at $\epsilon = 7 \times 10^{-5}$, dropping to the original value of 2.5×10^{-5} at the same temperature on returning to low amplitudes. However, oscillation at $\epsilon = 7 \times 10^{-5}$ above the hill (25°K) produced internal friction of 40×10^{-5} and on returning to low amplitudes, the low-amplitude internal friction had increased from its original value of 3.5×10^{-5} to 7.5×10^{-5} at 25°K. Annealing the specimen at a temperature < 150°K for 24 hours restored the original internal-friction hill. The modulus shows a temperature dependence approximately linear in the region from 4.3° to 2.5°K with a slope $\Delta M/M\Delta T \sim 6 \times 10^{-5}$/°K. Over the same region, the internal friction has a slope 0.5×10^{-5}/°K.

24,554 ANISOTROPY OF THE SNOEK PHENOMENON IN NIOBIUM by R.A. Hoffman and C.A. Wert (U. Illinois); Bull. Am. Phys. Soc., Vol. 9, pp. 213-214(A), Mar. 1964

A study has been made of the orientation dependence of the Snoek phenomenon in niobium. Measurements were performed on single crystals of niobium containing small concentrations of oxygen and nitrogen. The internal-friction measurements were performed using a piezoelectric-drive technique, the crystals being driven in a longitudinal mode of vibration at about 80 kc/sec. The measurements were performed on crystals of five different orientations ranging from $\Gamma = 0$ to $\Gamma = 0.32$ where $\Gamma = \alpha^2\beta^2 \times \beta^2\gamma^2 + \gamma^2\alpha^2$ with α, β, and γ being the cosines of the angles between the longitudinal axis of the specimen and the three basic cubic directions. The orientation dependence of the relaxation associated with interstitially dissolved oxygen was found to be the same as the relaxation associated with nitrogen. The results demonstrate that the internal friction is a maximum in the [100] direction and goes to zero in the [111] direction. Both the two extreme values of the internal friction and the intermediate values are consistent with the analysis presented by D. Polder.

2555 THERMALLY ACTIVATED DISLOCATION RELAXATION AND REVERSIBLE MICROSTRAIN IN REFRACTORY bcc METALS by H. Harper, J. Filloux [illegible] R.H. Chambers (Genl. Dynamics/Genl. Atomic); Bull. Am. Phys. Soc., [illegible]. 9, p. 230(A), Mar. 1964

[illegible]asurements of the internal friction and modulus-defect spectra associated [illegible]h thermally activated dislocation motion in Nb and Ta at oscillating shear-[illegible]ss amplitudes of up to 10^{-3} G show a certain range of amplitudes and tem-[illegible]atures ($> 3 \times 10^{-4}$ G, $< 250°K$) for which the internal friction as well as the [illegible]ulus defect decrease with increasing amplitude. In very pure specimens, [illegible] modulus defect exceeds 100 per cent in this range; the resulting reversible [illegible]ocation strains amount to several tenths of a per cent, and thus must be con-[illegible]ered part of the macroyielding process. It is further demonstrated that the [illegible]imum size of the modulus defect at these high amplitudes is controlled by [illegible] same temperature and frequency dependence as is found in the low-ampli-[illegible]e measurements of the modulus defect and internal friction associated with [illegible] α′, α, and β peaks. A model of the temperature and strain-rate dependence [illegible]he yield stress in the refractory bcc metals based on those results is outlined.

2556 DISLOCATION RELAXATION IN REFRACTORY bcc METALS by J. [illegible]oux, H. Harper and R.H. Chambers (Genl. Dynamics/Genl. Atomic); Bull. [illegible]. Phys. Soc., Vol. 9, p. 230(A), Mar. 1964

[illegible]e mechanical properties of Nb and Ta associated with relaxation of disloca-[illegible]ns whose mobility is controlled by thermal activation have been investigated [illegible]measurements made over wide ranges of temperature (5° to 500°K), frequen-[illegible](10^{-3} to 10^5 cps), oscillating strain amplitude (10^{-8} to 10^{-3}), torsional-bias [illegible]ss (10^{-5} to 5×10^{-3} G), and annealing conditions. In moderately pure speci-[illegible]s, there are nine resolvable internal friction peaks and associated modulus [illegible]ects, most of which closely obey an Arrhenius rate equation. The positions [illegible]emperature of the peaks measured at 10 cps are: α″ (~8°K), α′ (~40°K), [illegible]30°K), α_2(150°K), β_1(230°K), β_2(290°K), β_3(370°K), γ_1(490°K), γ_2(>510°K). [illegible] α and γ peaks are more resistant to annealing at 500°K than are the others. [illegible] α peaks are interpreted to be thermally activated double-kink generation [illegible]dge dislocations, while the β peaks are considered to be controlled by the [illegible]rmally activated constriction of dissociated screw dislocations; the α-primal [illegible]ks may be associated with geometrical kink motion over Peierls potentials, [illegible] the γ peaks may be associated with conservative jog motion.

2557 INTERNAL FRICTION OF SILVER CHLORIDE SINGLE CRYSTALS by [illegible]Fuakai and L. Slifkin (U. North Carolina); Bull. Am. Phys. Soc., Vol. 9, [illegible]263(A), Mar. 1964

[illegible]asurements of internal friction of nominally pure silver chloride single crys-[illegible] have been made at 35 kc/sec in longitudinal resonance at room tempera-[illegible]. The decrement of the freshly mounted crystal is time-dependent: the break-[illegible]away point in the curve of decrement vs amplitude shifts toward higher strain [illegible]plitude by a factor of approximately 3 during the first 24 hours and the slope [illegible]he strain-dependent region increases. After complete excitation in the high-[illegible]in region, the decrement decays with aging, initially following the $t^{2/3}$ [illegible] expected for a diffusion process. Decoration of the oscillating dislocations [illegible]h silver, produced photoelectrically, results in a significant decrease in [illegible]rement. Moreover, decoration displaces the breakaway point to larger strain [illegible]plitude and retards the rate of decay of decrement after high-stress excitation.

SOLID STATE DEVICES

DIODES

2558 WIDE-RANGE LOW CURRENT MEASUREMENTS OF DIODE REVERSE [illegible]RRENTS WITH AUTOMATIC RANGING FEATURES by C.E. James; IEEE [illegible]ns., Vol. IM-12, pp. 120-124, Dec. 1963

[illegible]method for measuring silicon diode reverse leakage currents is described. The [illegible]hnique is straightforward and provides wide-range, low current measurements [illegible]h improved accuracies and automatic ranging features. The full-scale indi-[illegible]ions extend from 10^{-3} through 10^{-10} amperes in eight decade ranges. The [illegible]l-scale accuracies achieved are better than ±0.5 per cent on ranges 10^{-3} [illegible]ough 10^{-8} amperes, ±1 per cent on the 10^{-9} ampere range, and ±10 per cent [illegible] the 10^{-10} ampere range. The automatic ranging feature exhibits a response [illegible]10 msec per range. The method is based on sensing the voltage drop (E_S) [illegible]oss a sensing resistor (R_S) in series with the reverse biased diode. The sens-[illegible] voltage is amplified to an appropriate level (E_O) which can be more easily [illegible]d accurately measured and/or digitized, depending upon the type of output [illegible]play and storage method used.

2559 SIMPLE ANALYTICAL APPROXIMATIONS TO THE SWITCHING [illegible]MES IN NARROW BASE DIODES by A. Grove and C. Sah (Fairchild Semi-[illegible]n. Res. Lab.); Solid-State Electronics, Vol. 7, pp. 107-111(L), Jan. 1964

[illegible]mple asymptotic expressions are derived to give the duration of the constant reverse current phase and the decaying reverse current phase for narrow base diodes. It is also shown that these expressions can be used for any diode whose base width is less than or equal to the diffusion length of minority carriers within the base.

24,560 CURRENT-VOLTAGE RELATION IN AN EQUILIBRIUM SPACE CHARGE (IN THE DRIFT DOMINATED REGION) by L. Gold (Kennecott Copper); J. Electronics and Control, Vol. 16, pp. 29-31, Jan. 1964

The current-voltage response of space charge in thermodynamic equilibrium is analyzed and a simple relationship expressing the thermalization of the electrostatic energy in the drift dominated region is obtained. The formula applicable to the planar diode in the limit of extreme collisional damping is then extended to allow for thermal energy ordinarily ignored in previous theories.

24,561 THE BNR DIODE, A CURRENT-CONTROLLED NEGATIVE-RESISTANCE DEVICE by W. Rindner and A.P. Schmid; IEEE Trans., Vol. ED-11, pp. 136-147, Apr. 1964

The bonded NR (negative-resistance) diode is a current-controlled negative-resistance device, fabricated in a similar manner as conventional gold-bonded diodes. Switching times of the device are a few nanoseconds. The I-V characteristic can be strongly controlled by magnetic fields and by illumination. Under continuous operation, magnetic sensitivity $(\partial V/\partial B)_I$ up to about 2.7 mv/gauss was observed under dc conditions, decreasing exponentially in an ac magnetic field above 2-3 kc, and disappearing around 25 kc. The sensitivity of the turnover voltage to illumination at a wavelength of 1.4 μ was found to be of the order of 10 mv/μw. The electrical and optical characteristics can be explained on the basis of Gunn's avalanche injection model. The magnetic sensitivity and an effect of the diode length on its I-V characteristics are compatible with lifetime modulation in the bulk material. Possible applications of the device as a magnetic and optical sensor are discussed, and an analysis of the device as an active circuit element utilizing its negative resistance is presented.

24,562 TiO_2 RECTIFYING BARRIERS by F. English and B. Gossick (Arizona State U.); Solid-State Electronics, Vol. 7, pp. 193-204, Mar. 1964

Measurements of the current-voltage characteristics, barrier capacitance, and distributions of the donor density within the potential barriers (as determined from the barrier capacitance) are presented for both gold-ceramic rutile rectifiers and gold-single crystal rutile rectifiers. The sample barriers have a thin insulating layer within the rectifying barrier between the gold contact and a semiconducting rutile substrate. Over a moderate range of applied voltage, the barriers on ceramic substrates follow the Mott-Schottky theory, but the forward current with large applied voltage is space-charge-limited.

24,563 EFFECT OF SOLUTION TRACE IMPURITIES ON I-V CHARACTERISTICS OF ELECTRODEPOSITED SURFACE BARRIER DIODES by G.M. Krembs and M.M. Schlacter (Philco Sci. Lab.); J. Electrochem. Soc., Vol. 111, pp. 417-420, Apr. 1964

Radioisotopes have been used to determine the surface concentrations of metallic impurities introduced on mechanically polished Ge surfaces during acid clean-up etching and jet electrodeposition. Reagent grade chemicals, to which were added radioactive metallic ions in the concentration range below 1 ppm, were used in the experiments. Surface coverage ranged from fractional monolayers in acid etching to several monolayers in jet electrolysis. In jet electrodeposition, autoradiograms revealed that noble metal impurities are chemically plated onto Ge electrodes, the distribution being a function of the hydrodynamic flow pattern, but independent of current density. The strong influence of these metallic impurities on the reverse I-V characteristics of surface barrier diodes is due to a p-type channel.

24,564 EFFECT OF CRYSTAL ORIENTATION ON Ge-GaAs HETEROJUNCTIONS by F.F. Fang and W.E. Howard (IBM Watson Res. Ctr.); J. Appl. Phys., Vol. 35, pp. 612-617, Mar. 1964

The electrical characteristics of Ge-GaAs heterojunctions, in particular n-n junctions, have been studied experimentally. Barrier voltages, determined from temperature dependence of reverse current and from capacitance vs voltage, depend upon the crystal orientation of the interface. This is seen to imply a corresponding variation of the conduction band discontinuities; namely $\Delta E_c[111]\ Ga > \Delta E_c[111]\ As > \Delta E_c[110]$. The voltage dependence of the reverse current is interpreted in terms of the shift of the Fermi level with respect to the conduction band edge in the accumulation layer. The transient behavior of n-n heterojunctions yields a switching time for 20 ma less than 10^{-9} sec, and no observed storage time.

24,565 METHOD OF MEASURING THE NEGATIVE RESISTANCE OF TUNNEL DIODES by I.I. Shagurin; News of Higher Ed. Inst., Min. of Higher and Sec. Spec. Educ., USSR, Radio Eng. Ser., pp. 155-164, Dec. 4, 1963; STAR, Vol. 2, p. 404(A), Feb. 23, 1964 JPRS-22132, OTS-63-41289, $4.00

A simple method is proposed for the measurement of the differential negative

resistance of tunnel diodes, using a minimum of necessary apparatus. This method does not have the shortcomings which are common to the bridge method and the voltage divider method. The measurement procedure, measurement error, and the measurement results using the proposed method are given. The results of the measurements show that the given method can be used for an exact measurement of the negative resistance of tunnel diodes in the voltage range $U_1 \leq U \leq U_2$. The measurement procedure is simple and calls for a minimum amount of apparatus. The oscillations occurring in the circuit have an amplitude of the order of 10 mv and more. Therefore, in order to fix them, an indicator of relatively low sensitivity is required.

24,566 TUNNEL-DIODE SWITCHING TIME AND ITS DEPENDENCE ON DIODE NONLINEARITIES by J.A. Narud and C.S. Meyer (Motorola Semicon. Prod.); IEEE Trans., Vol. CT-11, pp. 122-128, Mar. 1964

The switching time of a tunnel diode is studied without resorting to the usual straight-line approximations for the diode characteristic. It is shown that switching time is dependent upon some average of the nonlinearities in the circuit, whereas dependency upon the detailed behavior of these nonlinearities is implied in the piecewise-linear approach. In view of the analysis it is apparent that the magnitude of the negative resistance of the diode is of no consequence in determining switching time. An expression for switching time is developed in the form of a figure-of-merit multiplied by a power series in the threshold to trigger-magnitude ratio. The coefficients of the series are explicitly defined and essentially insensitive to variations in load resistance and diode characteristic. For the accuracy usually required, the series may be truncated after three terms. With a constant threshold to trigger-magnitude ratio, the figure-of-merit multiplier provides a simple means of evaluating the switching time. The series representation for switching time can be used in the selection of a load line for a circuit or as a guide in the choice of diodes for a specific application.

24,567 MAGNETIC-FIELD DEPENDENCE OF DIRECT INTERBAND TUNNELING IN Ge by H. Roth, W. Bernard, W.D. Straub (Raytheon) and J.E. Mulhern, Jr. (U. New Hampshire); Bull. Am. Phys. Soc., Vol. 9, p. 273(A), Mar. 1964

An investigation has been made of the effect of magnetic fields up to 20 kg on the reverse current in Ge tunnel diodes at T = 1.8°, 4.2°, and 78°K. It has been observed that the application of a magnetic field results in a distinct reduction in the tunnel current (~a few per cent at 20 kg) at reverse biases corresponding to the onset of direct band-to-band tunneling. The data appear to be analogous to those reported by Fritzsche and Tiemann using Ge tunnel diodes subjected to mechanical stress. In addition, measurements were made of the increase in voltage ΔV required to restore the current to its zero magnetic-field value. Above the "Kane kink," $\Delta V \sim$ several tenths of a millivolt of 20 kg. Both $\Delta I/I$ and ΔV are proportional to H^2, and assume their maximum values for H perpendicular to I. The effect is more pronounced in Sb-doped Ge diodes than in those doped with As, and the onset of the effect is more sharply defined at the lower temperatures.

24,568 ANISOTROPIC STRESS-INDUCED EXCESS CURRENT IN TUNNEL DIODES by W. Bernard, W. Rindner and H. Roth (Raytheon); Bull. Am. Phys. Soc., Vol. 9, p. 273(A), Mar. 1964

Large reversible changes in the excess current of germanium and silicon tunnel diodes subjected to anisotropic stress have been studied. The relationship of this effect to the anisotropic stress effect recently reported by Rindner and Braun in conventional p-n junctions is discussed. It is suggested that both effects may arise from deep-lying electronic states associated with strain-induced lattice defects in the junction region. A consistent interpretation is presented of the tunnel-diode excess current in terms of strain-induced intermediate tunneling states, and of the conventional diode current in terms of strain-induced generation-recombination centers.

24,569 SILICON AVALANCHE RECTIFIERS by G. Duddridge (Stand. Tel. and Cables Ltd.); Electronic Engrg., Vol. 36, pp. 247-249, Apr. 1964

The manufacture and the characteristics of silicon avalanche rectifiers are described and it is pointed out that this type of rectifier has the ability to absorb reverse over-voltage transients. Both series and parallel operation are dealt with and applications are described.

24,570 STUDIES OF RADIATION DAMAGE IN SILICON AVALANCHE DIODES by R.H. Haitz, R. Gereth (Shockley Res. Lab.) and F.M. Smits (Sandia Lab.); Bull. Am. Phys. Soc., Vol. 9, p. 288(A), Mar. 1964

Small-area uniform avalanche diodes in silicon exhibit breakdown characteristics similar to those observed in microplasmas. In particular, the noise pulse rate depends on the presence of traps. For constant trap density, this rate varies linearly with charge passing the junction per current pulse. Irradiating the diodes with 2-Mev electrons increases the pulse rate proportionally to the time-integrated flux. Since, in the active volume of the breakdown region of about 5×10^{-12} cm^3, the number of atoms displaced by the electrons is comparable to the number displaced in one primary neutron collision, observable changes should result from such collisions. To check this, diode sets were irradiated with fast neutrons to time-integrated fluxes corresponding to probabilities between 10% and 90% of at least one primary neutron collision within the active volume. A correlation between the fraction of diodes with significant changes in the pulse rate (more than twice) and the collision probability has been found. One can, therefore, conclude that radiation damage resulting from a single primary neutron collision is observed.

24,571 20-VOLT AVALANCHE DIODES AS NOISE GENERATORS by K.O. Otley (Harry Diamond Labs.); Nov. 5, 1963, 26 pp.; U.S. Gov. Res. Rep., Vol. 39, p. 40(A), Apr. 10, 1964 AD 428 717 OTS $2.60

Measurements of noise output and observations of noise spectrum were made on 20-v silicon avalanche diodes (often called Zener diodes) over the range of noise-producing voltage at -40, 75, and 160°F. Six types from five manufacturers were selected for this test. Each diode type evaluated was obtained from a single manufacturer. Among those tested, type 1N1317A is believed most suitable for use as a noise generator, but planar diodes are preferred in all circuits in which a sufficiently high supply voltage is available.

24,572 VARACTOR DIODE DOPING DISTRIBUTION FOR HIGH EFFICIENCY AND LARGE POWER CAPABILITY FREQUENCY DOUBLERS by R. Ward (Lockheed Missiles and Space); Proc. IEEE, Vol. 52, pp. 322-333(L), Mar. 1964

The varactor diode doping distribution that yields the voltage-elastance function for optimum efficiency as a frequency doubler is described. The relationships between the physical diode design parameters and the optimum electrical diode characteristic parameters are shown. A possible method of how the optimum diode doping density might be achieved is suggested.

24,573 TURN-ON CRITERION FOR p-n-p-n DEVICES by F. Gentry (GE); IEEE Trans., Vol. ED-11, p. 74(L), Feb. 1964

A derivation demonstrating that a p-n-p-n device begins to switch when the sum of the small signal alphas reaches unity is given. It is shown that if the sum of the small signal alphas is unity, an infinitesimal increase in gate current, temperature, or voltage will cause a p-n-p-n device to begin switching.

24,574 NOW THE GATE TURN-OFF SWITCH SPEEDS UP D-C SWITCHING by D.R. Grafham; Electronics, Vol. 37, pp. 64-71, Mar. 23, 1964

A gate turn-off switch which operates at frequencies up to 100 kc is described. Like the silicon controlled rectifier, it is a three-terminal, four layer p-n-p-n switching device. However, it can be turned on and off by its gate input terminal with a low power pulse of less than 10 microsec, and once turned on, it does not need a continuous signal like the power transistor. The GTO is a low power device, with the largest commercially available GTO being rated at about 7.5 amps at 500 to 600 volts. Six applications of the GTO are described: a flip-flop, ring counter, sawtooth generator, voltage regulator, high frequency chopper, and high voltage generator.

24,575 A SILICON-GLASS SEALED MICROMINIATURE LOGIC DIODE by J.H. Forster and I.M. Mackintosh; Solid State Design, Vol. 5, pp. 19-21, Mar. 1964

A new microminiature logic diode (the "pinhead" diode) has been fabricated by hermetically sealing a silicon mesa wafer to a low-resistivity silicon end cover by means of a hard glass annular washer. The glass is sealed to the silicon by heating this assembly under moderate pressure in a dry ambient at temperatures up to about 800°C. This hot seal, following a simple but rigorous pre-cleaning of the piece parts, gives 50 per cent step-stress failures at 490°C for two hour intervals, with an activation energy of 1.9 ev. The device, about 40 mils in diameter and about 20 mils in height, can be bonded or brazed directly to film or printed circuitry.

Injection Luminescence of GaAs Diodes - See 24,368

Recombination:
Luminescence in GaP Diodes - See 24,369
Radiation from GaP Diodes - See 24,370

Injection Electroluminescence in Cu_2S-ZnSe and Cu_2Se-ZnSe Heterojunctions - See 24,372

TRANSISTORS

24,576 COMPARATIVE OPERATING LIFE TESTS ON P-N-P GERMANIUM POWER TRANSISTORS FROM AMERICAN, EUROPEAN AND JAPANESE MANUFACTURERS by M.J.O. Strutt and C. Villalaz (Swiss Fed. Inst. Tech.); Scientia Electrica, Vol. 10, pp. 24-39, 1964

Samples of 6 Ge p-n-p power transistors from different manufacturers have been

bjected to an operating life test lasting about 5,000 hours. A mounting base nperature of 75°C was chosen; the power dissipation was calculated in such way that the junction temperature reached the maximum permissible value in- cated by the manufacturer. During aging, the dc current gain h_{FE}, the col- ctor leakage current I_{CBO} and the emitter-base voltage V_{BE} were measured. If all these parameters, calculated relative to their initial value, only the ximum, minimum and median values are plotted vs aging time. Curves show- g a different behavior compared with the trend of that of the majority are own in separate figures (outsiders). To estimate the aging behavior of the pes from different manufacturers, criteria have been given by which use of e most suitable type for a certain purpose may be found. These criteria are plied to the life test results in question, and a detailed elaboration by the e of ranking methods is demonstrated.

,577 TESTING TRANSISTORS WITH RING COUNTERS by W.P. Barnett pE); Electronic Prod., Vol. 6, pp. 34-35, 82-83, Jan. 1, 1964

transistor test setup which replaces stepping switches by ring counters and ed relays is described. The advantages of this system are: higher operating eeds; freedom from routine maintenance; ability to change the number of test sitions; and shorter downtime in the event of malfunction. The main disad- ntage is higher initial cost. The ring counter was constructed with silicon ntrolled switches. Due to low operating levels, failures are rare, but a lt detection circuit is provided.

,578 TRY EPITAXIAL TRANSISTORS FOR SUPERSATURATED SWITCHING J. Giorgis (GE); Electronic Design, Vol. 12, pp. 60-69, Jan. 20, 1964

e advantages of the silicon planar epitaxial transistor with base ring construc- on over either the germanium or silicon alloy transistor as a supersaturated itch are discussed. The epitaxial transistor has a much higher h_{FE} at low cur- nts, resulting in a lower offset voltage. Theory and experiment are seen to in close agreement for the offset voltages of the two types of transistors. It also shown theoretically as well as experimentally that the epitaxial transis- r has a much higher inverse current gain than the silicon alloy transistor, re- lting in a lower dynamic ON impedance. Conditions for insuring transistor turation are discussed, and methods for determining parameters used in the eory are given.

,579 A REAPPRAISAL OF CERTAIN ASPECTS OF TRANSISTOR THEORY by J. Sparkes (Imperial Coll. Sci. Tech., London); J. Electronics and Control ol. 16, pp. 153-168, Feb. 1964

the usual analyses of transistor action various assumptions are frequently made; r example, that space charge neutrality exists in the base region, that p-n nctions are depleted of mobile carriers, that minority carrier densities next reverse biased junctions are near zero, etc. It is shown that none of these sumptions is strictly valid. A new examination of the problem, in which these sumptions are put in better perspective, leads to: (a) a complete, partially merical, analysis of abrupt p-n junctions in equilibrium showing the spatial stribution of holes, electrons and field; (b) a qualitative discussion of these istributions when current is flowing; (c) a new expression for the small sig- al capacitance of abrupt p-n junctions; (d) a new space-charge-neutral solu- on for the complex current gain of transistors (this is compared with Shockley's lution). Finally, a preliminary numerical solution of the carrier and field istribution in a collector junction, under conditions of reverse bias and large verse current, is shown.

4,580 NEW ASPECTS OF SECOND BREAKDOWN IN TRANSISTORS by B. eich (USAERDL); Solid State Design, Vol. 5, pp. 23-27, Apr. 1964

has been found that the nature of "second breakdown" is more basic than eretofore recognized. The study has revealed that "second breakdown" is ex- ibited in both collector-to-base and emitter-to-base diodes of the transistors s well as voltage regulator diodes. The only restriction on this observation is at the applied diode voltage must be in excess of the sustaining second break- own voltage. From the nature of the observed thermal resistance characteris- ics of transistors, it has been assumed that second breakdown is thermal in na- ure. On this basis an expression has been developed which leads to a first or- er prediction of the open base breakdown current.

4,581 BULK RELIABILITY EFFECTS IN SEMICONDUCTOR DEVICES; CUR- ENT CROWDING IN TRANSISTORS by B. Reich and E.B. Hakim (USAERDL); olid State Tech., Vol. 7, pp. 23-28, Apr. 1964

he problem of current crowding in transistors and its relationship to transistor erformance are reviewed. A method is shown whereby a quantitative value an be assigned as a measure of the extent of crowding that occurs. The possi- le implications of current crowding in the operational reliability is described. n empirical figure of merit is developed relating the crowding factor to the hysical parameters of the semiconductor device. Recommendations in device esign are made which should improve the current handling capability of tran- istors.

24,582 THE MINORITY CARRIER STORAGE EFFECT IN THE COLLECTOR REGION AND THE STORAGE TIME OF TRANSISTORS by H. Yanai, T. Sugano and K. Tada (U. Tokyo); Proc. IEEE, Vol. 52, pp. 312-314(L), Mar. 1964

The effect of minority carrier storage in some kinds of junction transistors and diffused base transistors, whose collector resistivity and collector minority carrier lifetime are large, is discussed. Formulas for the storage time, T_s, valid for relatively low frequencies are derived for three cases: (1) in which the collector injection efficiency γ_I is very near to unity; (2) $\gamma_I \ll 1$ and the width of the collector W_c is much greater than the diffusion length of electrons in the collector L_n; and (3) $\gamma_I \ll 1$ and $W_c \ll L_n$. It is concluded from these considerations that the storage time of mesa transistors can be reduced remarkably by introducing trap impurities into the collector region or by reducing W_c by an epitaxial structure.

24,583 GETTING INSIDE THE TRANSISTOR WITH LUMPED PHYSICAL MODELS. Part II by D.J. Hamilton and F.A. Lindholm (U. Arizona); Electronic Design, Vol. 12, pp. 46-51, Mar. 30, 1964

A lumped physical model of a transistor useful for transient calculations is presented. The model consists of parallel arrangements of storances and combinances. Combinance is a lumped element representing the absorption of hole electron pairs according to the density of the minority carriers, and storance is a lumped element representing storage of minority carriers. The model is useful in computing dynamic terminal characteristics such as alpha cutoff frequency and storage time, and can be used to calculate storage time when the input transient is introduced at the collector.

24,584 RISE AND FALL TIME CALCULATIONS OF JUNCTION TRANSISTORS by H.J. Kuno; IEEE Trans., Vol. ED-11, pp. 151-155, Apr. 1964

Expressions for rise and fall time calculations of junction transistors are derived based on the charge controlled model. In solving the differential equation of the charge controlled model, a new approach is taken and exact solutions are obtained. Comparison of the experimental results of the rise and fall time measurements with the theoretical prediction, using the measured transistor parameters, shows very good agreement.

24,585 AN EXPERIMENTAL STUDY OF 1/f NOISE IN TRANSISTORS by M. J. Wiggins (Martin Co.); IEEE Trans., Vol. BTR-10, pp. 84-92, May 1964

An experimental approach to the determination of optimum operating point and source impedance for transistor circuits in applications where 1/f noise predominates is outlined. Results of a number of tests which measure the noise spectrum as a function of operating point and source impedance are described. Results of such tests are presented as parametric plots of noise factor versus frequency, and conclusions are drawn as to the choice of parameters for optimum noise performance at low frequencies. A description of the special measurement techniques is included. A procedure is developed for rapid determination of the entire noise spectrum of a transistor for practical design purposes.

24,586 LINE SCANNING TRANSISTOR — DISSIPATION DURING SWITCH-OFF by F.D. Bate (Thorn-AEI Radio Valves and Tubes Ltd.); Electronic Engrg., Vol. 36, pp. 170-172, Mar. 1964

An analysis is made of the power dissipated in a television line scanning transistor during the switch-off period T_{co} for different shapes of collector current fall. Fundamental frequency only and third harmonic tuning conditions are both considered and compared. It is found that, to a first approximation, the power dissipated always varies as the square of the cutoff time T_{co} and is 50 per cent greater when optimum third harmonic tuning is employed when compared with the case of fundamental frequency only being present.

24,587 THE ELECTRICAL PROPERTIES OF HIGH-FREQUENCY TRANSISTORS by H.G. Bassett and P.E. Greenaway (P.O. Res. Station); P.O. Electrical Engrg. J., Vol. 57, pp. 54-59, Apr. 1964

The use of diffusion as a technique for making transistors has complicated their circuit behavior, particularly at high frequencies. The graded-base transistor's properties at high frequencies are examined using the charge-control approach for both amplifying and switching operations.

24,588 SMALL-SIGNAL, HIGH-FREQUENCY THEORY OF FIELD-EFFECT TRANSISTORS by A. Van Der Ziel and J.W. Ero; IEEE Trans., Vol. ED-11, pp. 128-135, Apr. 1964

In this theory a field-effect transistor of planar geometry is considered as an active, distributed, nonuniform transmission line. The wave equation of this line is determined and solved by an approximation method. From this solution the y parameters are determined. By comparing the results for y_{11} with van der Ziel's expression for the high-frequency gate noise of field-effect transistors, it is shown that the noise temperature of y_{11} is of the order of the device temperature. The conductance part g_{11} of y_{11} varies as ω^2 over a wide frequency range. The high-frequency cutoff of the field-effect transistor is determined.

24,589 A DEVELOPMENTAL STUDY OF A HIGH FREQUENCY UNIPOLAR FIELD EFFECT TRANSISTOR by L. Ragle and M. Purnaiya (Fairchild Semicon.); Sept. 1963, 35 pp., Contract AF33 657 8718; U.S. Gov. Res. Rep., Vol. 39, p. 33(A), Apr. 20, 1964 AD 428 051 OTS $4.60

The design, construction, and performance of a very small active area field effect transistor are discussed. The input impedance at 100 Mc is predominantly capacitive, and high input impedance is obtained by making the device area as small as possible. High transconductance is sought by making an interdigitated structure. The important experimental design considerations taken into account, together with fabrication problems which arose during the FET developments, are discussed. Also discussed are those factors which influenced yield, the most important of which were the photolithographic steps. The dc electrical characteristics obtained with two different geometries of field effect devices are discussed. These characteristics are related to the device geometry and diffusion structure to the extent that this is possible. The high frequency characteristics of the device in terms of Y matrix characterization are noted. An equivalent circuit model is derived, and performance is compared with design objectives.

24,590 THE FIELD-EFFECT TRANSISTOR — AN OLD DEVICE WITH NEW PROMISE by J.T. Wallmark (RCA); IEEE Spectrum, Vol. 1, pp. 182-191, Mar. 1964

A summary of the characteristics and the performance limits of field-effect transistors to the extent that they differ from bipolar transistors is presented. An assessment of the technical possibilities of unipolar field-effect transistors as active devices and as building blocks for integrated circuits is made. Input impedance, current-voltage characteristics, bilateral symmetry, radiation tolerance and noise behavior are discussed in detail. A tabulation of semiconductor materials which are potentially useful for field-effect transistors is presented. The geometry of the field-effect transistor permits it to be incorporated into integrated circuits more readily than the bipolar transistor. Advantages of the field-effect transistor over the bipolar transistor in redundancy and multiple units are discussed.

24,591 POWER-LAW NATURE OF FIELD-EFFECT TRANSISTOR CHARACTERISTICS by J. LeMee (Westinghouse) and A. Martin (Electronique et Automatisme, France); Proc. IEEE, Vol. 52, pp. 314-315(L), Mar. 1964

The applicability of Richer and Middlebrook's experimental justification of a power-law relationship between drain current and gate voltage [Proc. IEEE, p. 1145, Aug. 1963] to cylindrical structure field-effect transistors (tecnetrons) is discussed. The question of the dependence of the experimental drain current - gate voltage characteristics on device geometry is considered. Richer and Middlebrook worked with planar devices, while the authors studied the cylindrical geometries. The author's conclusions have been published elsewhere [J. Physique Rad., Vol. 22, p. 1A, 1961] and [J. Physique Rad., Vol. 22, p. 83A, 1961].

24,592 FIELD EFFECT TRANSISTORS UNDER NUCLEAR RADIATION by A.B. Kaufman; Electronic Ind., Vol. 23, pp. 94-97, Mar. 1964

Certain operating parameters of field effect transistors, which degrade opposite to those of conventional transistors exposed to a nulcear environment, are discussed. Transistors exposed show increased I_{CBO}, or in grounded emitter operation in increase in I_C, whereas field effect transistors show a decrease in I_{DSS}. Also, the gate voltage required for I_{DSS} cutoff decreases, and therefore the use of a fixed bias voltage would lower the nuclear resistance of a circuit using field effect transistors.

24,593 FIELD EFFECT TRANSISTORS. COMPARATIVE EFFECTS OF 1 Mev ELECTRON IRRADIATION ON FIELD EFFECT AND INJECTION TRANSISTORS by C.S. Roberts and J.A. Hoerni (Ameico, Inc.); Tech. Bull. No.1, Mar. 1963, 6 pp.; STAR, Vol. 2, p. 505(A), Feb. 23, 1964

Degradation characteristics of semiconductor devices under electron irradiation similar to that found in high-altitude radiation belts show that the field effect transistor will still be operable at total dosages between 1000 and 10,000 times greater than will be endurable with conventional high gain injection transistors. The degradation of the latter is particularly severe at the low collector current levels used for high input impedance applications.

Photo-Field Effect Transistors - See 24,608 and 24,609

24,594 THE UNIJUNCTION TRANSISTOR, ITS OPERATION AND APPLICATIONS by H.R. Henly (G.P.O. Engrg. Dept.); Wireless World, Vol. 70, pp. 110-112, Mar. 1964

A brief description of the construction, operating characteristics, and applications of the unijunction transistor is presented. Applications mentioned include the relaxation oscillator (very common, useful in triggering silicon controlled rectifiers), a square wave generator, and an integrating counter circuit.

24,595 SEMIDISTRIBUTED NEURISTOR LINE USING UNIJUNCTION TRANSISTORS by A. Ambroziak (Polish Acad. Sci., Warsaw); Solid-State Electronics, Vol. 7, pp. 259-265, Apr. 1964

A new semiconductor device which may be used as a decade counter or as a semidistributed neuristor line is described. This device consists of unijunction-transistor-like stages which have a common base-one region. The construction, principle of operation, characteristics and results of investigation of this device are described.

24,596 METAL BASE TRANSISTOR PUSHES BACK THE FREQUENCY BARRIER by D.V. Geppert and R.A. Mueller (Stanford Res. Inst.); Electronics, Vol. 37, pp. 42-46, Mar. 13, 1964

A metal-base transistor, consisting of a thin molybdenum metal film sandwiched between two n-type silicon semiconductors, with an upper frequency limit of 10 Gc is described. Emitter injection efficiency is independent of base thickness since the electron current is not diffusion limited, but obeys a thermionic emission law. The device is similar to an n-p-n transistor except for the emitter-injection process and the base-transport mechanism. A broadband amplifier using a metal-base transistor in a grounded-base configuration to provide 20 db gain at Gc is presented. Additional development work is expected to increase the upper frequency limit of the metal-base transistor to 100 Gc.

24,597 POTENTIAL DISTRIBUTION IN THIN OXIDE FILMS by T.W. Hickmott (GE); Bull. Am. Phys. Soc., Vol. 9, p. 297(A), Mar. 1964

The potential distribution in Al-SiO-Al-SiO-Au triodes with SiO thicknesses of a few hundred A has been studied, using the center Al electrode (grid) as a probe. Current-voltage characteristics of triodes are identical to those of Al-AiO-Au diodes. Development of a voltage-controlled negative resistance (VCNR) in the triode is accompanied by a concentration of potential near the negative electrode. The high-field region of the insulator is about 120 A in thickness. If triode potentials are reversed after developing conductivity, negative resistance is still found in the current-voltage characteristic of the triode but the potential distribution in the triode is only sightly changed. The high-field region remains at the electrode that was originally negative. VCNR in thin oxide films is a high-field phenomenon but does not depend on field emission of electrons from the metal electrodes. Conductivity in the bulk of the SiO insulation is ohmic. Potentials between the gold electrode and the grid are proportional to the triode current, which is determined by processes in the high-field region of the insulation. Similar phenomena are found in Al-Al_2O_3-Al-Al_2O_3-Au triodes.

Diffused GaAs Transistors - See 23,743

24,598 A SILICON SYMMETRICAL TRANSISTOR UTILIZING AN EPITAXIALLY GROWN BASE REGION by I. Sasaki; IEEE Trans., Vol. ED-11, pp. 115-121, Mar. 1964

A silicon symmetrical transistor having high symmetry of current gains, extremely low saturation resistance and high-frequency performance is described. High injection efficiencies of the two junctions are obtained owing to the high surface concentration of the emitter and the high impurity concentration of the wafer. A thin base of about 2 μ in thickness, large junction areas of about 0.7C mm in diameter and the junction area ratio of about 0.9966, are used for high survival factors. The collector junction is formed in the epitaxial layer intentionally away from the interface, in order to have a nearly equal impurity distribution to that near the emitter, and to keep away from the crystal imperfections near the interface. Good symmetry of current gains is obtained: the h_{FE}'s above 20 in the two directions at 10 μa to above 50 ma of collector currents. The saturation resistance is in the neighborhood of 1 Ω. Current gain bandwidth f_T is greater than 20 Mc.

24,599 NEW TECHNOLOGY SPARKS AN EXPANSION FOR GERMANIUM by K.B. Landress; Electronics, Vol. 38, pp. 62-65, Apr. 6, 1964

General-purpose germanium transistors built with a planar structure are described. The planar structure proves superior to the typical mesa structure with regard to breakdown characteristics, moisture resistance, mechanical reliability and expanded contacts. These transistors should be useful wherever high frequency (1 to 10 Gc) transistors are desired at operating temperatures below 100°C. This would include such applications as L-band phased array radar, television tuners and computer switching circuits.

24,600 SIMPLE TECHNIQUE FOR MAKING AN ELECTRIC CONTACT ON SILICON by J. Flores (Cent. d'Etudes Nuc. Saclay, France); Rev. Sci. Instr. Vol. 35, pp. 112-113(L), Jan. 1964

A method for making an ohmic contact on high resistivity Si without heating the whole crystal is described. By sparking on the Si surface with two Au-Sb or Al electrodes (depending on the Si type), contacts have been obtained at temperatures as low as that of liquid nitrogen. These sparked contacts are highly reliable, having the advantages of the simple equipment and short firing time when compared with a vacuum or electrolytic bath metalization.

OPTICAL DEVICES

PHOTOELECTRIC DEVICES

601 COMMUNICATION CHANNEL MODEL OF A PHOTOELECTRIC DETECTOR by L.P. Bolgiano, Jr. and L.F. Jelsma (U. Delaware); Proc. IEEE, Vol. 52, pp. 218-219(L), Feb. 1964

A communication channel model of a photoelectric detector was developed, relating classical field energies as input and the number of counts in any one coherence time as output. On the basis of such a model, assuming maximum entropy counting statistics, it is found that at most, 50 per cent of the average information in the number of counts in successive coherence times conveys information about the energy of the classical field.

602 PHENOMENA OF IMAGE SHARPNESS RECOGNITION OF CdS AND CdSe PHOTOCONDUCTORS by P. Pargas (LogEtronics); J. Optical Soc. Am., Vol. 54, pp. 516-519, Apr. 1964

A theory is presented to account for the fact that a photoconductive cell can detect when an image projected on it is in sharpest focus. Each of the small particles in the photoconductive surface is treated as an individual photoconductor in series-parallel connection with all the other particles. When the distribution of light on the surface of such a photoconductive cell is varied (total incident flux being constant) the total conductance across the whole surface of the cell depends upon detail contrast, acutance, and other factors of the projected image. The observed dependence of conductance on sharpness of focus can be explained by this theory.

603 LIGHT SENSORS: BRIGHT FUTURE FOR AN EXPANDING TECHNOLOGY - Part I by D. Abel (Texas Instr.); Electronic Design, Vol. 12, pp. 24-, Feb. 3, 1964

Photoconductive and photovoltaic light sensors are compared with respect to material types, output power, and applications. A brief review of the terminology of light measurement is given, and a more extensive comparison of photoconductive light sensor characteristics is made. Polar graphs of the directional properties of the photodiode are given.

604 A THEORY OF STRONGLY DOPED PHOTODIODES WITH ABRUPT JUNCTION [in French] by H. Dormont and M. Valton (Lab. d'Electron. et Phys. Appl., Paris); Acta Electronica, Vol. 6, pp. 291-339, Oct. 1962

An extensive theory of the unidimensional abrupt photodiode is carried out with the help of the following classical assumptions: (1) Impurity concentrations (of both n and p types) are large; donors and acceptors are ionized; (2) Recombination centers are present on a single level in the vicinity of the forbidden band; (3) An external EMF, depending on the time t, is applied between the extremities of the junction; (4) A monochromatic light beam, the intensity of which is also depending on the time, generates electrons and holes in the bulk of the material; (5) Surface recombinations may take place at both ends; and (6) The thickness of n and p type regions may be given any value, larger or smaller than the diffusion lengths. The classical diffusion continuity and Poisson equations are used to solve the problem of the dynamical behavior of the system, including the effects of time variations and transient phenomena. A general analysis of transient energy exchange phenomena provides formulae for the energy stored in the system.

605 STORAGE PHENOMENA IN PHOTODIODES: THE GERMANIUM JUNCTIONS AS A TYPICAL CASE [in French] by M. Robert (Lab. d'Electron. et Phys. Appl., Paris); Acta Electronica, Vol. 6, pp. 341-407, Oct. 1962

The storage phenomenon is not observable at room temperature but it can be made evident by suitable cooling. Theoretical notions about working conditions of p-n junctions are recalled and the influence of cooling on photodiode behavior is experimentally studied in the 300°-78°K temperature range. The temperature-dependence of the dark current-voltage curve is shown, and photoelectric effects (photoelectric current, open-circuit voltage) in a lighted photodiode are examined. From these results, the conditions required for storage phenomenon observation in an illuminated photodiode are determined. A theoretical study and experimental measurements make it possible to clarify this phenomenon and its laws. Oscillograms are presented, obtained in various temperatures and light conditions, which make it possible to calculate the charge stored in a photodiode. This experimental study shows that the storage phenomenon promises applications (for example the realization of photosensitive layers for near infrared image scanning tubes) when photodiodes are used with a reverse bias at temperatures of about 200°K.

606 CARTRIDGE-TYPE POINT-CONTACT PHOTODIODE by W. Sharpless (Bell Labs.); Proc. IEEE, Vol. 52, pp. 207-208(L), Feb. 1964

A point-contact photodiode capable of detecting microwave beat frequencies in the output of optical masers is described. The diode consists of a 10 μ p-type Ge film deposited on a highly doped p-type Ge substrate; the device is mounted on the end of a Kovar tube. Electrojet etching reduces the central portion of the film to 1 μ. S-shaped contact points of 1/2 mil As-doped Au ribbon were formed by either applying reverse dc pulses or exposure to the output of a 0.6328 μ HeNe maser beam while under reverse bias. The maser formed diode was found to be more sensitive. The diodes were able to detect maser beat frequencies of 2.1, 14 and 18 Gc and higher order beats of 30 Gc.

24,607 THE TRANSIENT BEHAVIOR OF TRANSISTORS DUE TO IONIZING RADIATION PULSES by R. Caldwell (Boeing), D. Gage and G. Hanson (U. Washington); Commun. and Electronics, No. 64, pp. 483-491, Jan. 1963

The mechanism of secondary photocurrent generation in transistors due to short ionizing radiation pulses is discussed quantitatively and the results of 0.2 μsec flash X-ray experiments are evaluated. The observed effects can be explained by the temporary storage of majority carriers in the depletion layer and the diffusion capacitances associated with the emitter junction. The dependences of the transient photocurrent pulse on transistor type, radiation dose, initial bias level and external circuit impedance are described. An equivalent circuit controlled by stored base charge was developed to predict the transient response of transistor circuits.

24,608 PHOTOFET CHARACTERISTICS AND APPLICATIONS by M. Shipley; Solid State Design, Vol. 5, pp. 28-30, Apr. 1964

High-impedance, low-noise properties of the field-effect transistor combined with the basic properties of the photodiode provide a sensitive, linear and stable photosensitive field-effect transistor PHOTOFET. This paper discusses the basic parameter definitions and measurement methods; typical applications are presented to best demonstrate the advantages of the PHOTOFET over other photodetectors. A qualitative comparison of photosensitive devices is also discussed. Unipolar field-effect transistor properties permit biasing PHOTOFETs for zero temperature coefficient of drain current and are highly nuclear radiation resistant.

24,609 A HIGH SENSITIVITY SOLID STATE LIGHT DETECTOR by S. Cohen (MIT); Aug. 1963, 81 pp., NASA Grant NsG 254-62; STAR, Vol. 2, p. 505(A), Feb. 23, 1964 NASA CR-55164; TE 6, OTS $8.10 ph, $2.63 mf

A gallium arsenide photovoltaic cell is combined with a field effect transistor to make a solid-state light detector. This detector is found to be capable of sensing stellar radiation.

GaP Solar Cells - See 23,786

Mica Filters for Lasers - See 24,675

OPTICAL MODULATORS

Optical:
Modulators - See 24,447
Demodulators - See 24,610

24,610 EVALUATING LIGHT DEMODULATORS by D.E. Caddes and B.J. McMurtry; Electronics, Vol. 37, pp. 54-61, Apr. 6, 1964

A method for comparing various designs of the light detector element in laser communications or radar systems is discussed. Three major criteria are quantum efficiency, current multiplication factor, and equivalent load resistance. The different devices considered include electrostatic photomultiplier tubes, crossed-field photomultipliers, vacuum photodiodes, photoklystrons, distributed-emission photodiodes, traveling-wave phototubes, multiplier traveling-wave phototubes, bulk photoconductors, semiconductor photodiodes, and photo-parametric detectors.

24,611 SOME OPTICAL MODULATION AND DEMODULATION TECHNIQUES by M.R. Wohlers (Grumman Aircraft); Aug. 1963, 25 pp., RN-166; STAR, Vol. 2, p. 742(A), Mar. 23, 1964

The use of electro-optic crystals for modulation and some techniques which have been proposed are discussed. Some additional schemes which appear to be promising are proposed or reevaluated. The approach taken is heuristic in that some devices discussed are time-varying systems, and the theory used is that of slow-time variation.

Electro-Optic Modulators for Lasers - See 24,677

24,612 STRAIN EFFECTS IN ELECTRO-OPTIC LIGHT MODULATORS by I.P. Kaminow (Bell Labs.); Appl. Optics, Vol. 3, pp. 511-515, Apr. 1964

The KDP rod in an electro-optic light modulator is heated uniformly in its cross

section by the RF field but is cooled only at the surface. Therefore, a radial thermal gradient exists in the rod. It is shown experimentally and analytically that this gradient degrades the performance of the device when operated as an intensity modulator. For example, about 2 W dissipated in a cylindrical KDP rod of any dimensions will reduce the degree of intensity modulation by one half. The sources and effects of random-phase retardation are also considered briefly.

24,613 ELECTRO-OPTIC LIGHT BEAM DEFLECTOR by V. Fowler, C. Buhrer and L. Bloom (Genl. Tel and Electronics Res. Labs.); Proc. IEEE, Vol. 52, pp. 193-194(L), Feb. 1964

The rapid deflection of light beams by an electro-optic refracting medium is described. The refractive index of the medium transverse to propagation may be varied linearly by an electric field. At room temperatures values of Δn larger than 10^{-4} may be produced. Linear variation of n with distance may be obtained through application of nonuniform electric fields.

MASERS and LASERS

CHARACTERISTICS

24,614 MASERS by W.H. Higa (Jet Prop. Lab.); July 26, 1962, 21 pp., NASA Contract NAS7-100; STAR, Vol. 2, p. 751(A), Mar. 23, 1964 NASA CR-53044; JPL-TM-33-95, OTS $2.60 ph, $0.83 mf

The following discussion of masers is intended primarily for the electronics engineer interested in a quick introduction to the subject. After a concise review of the physics of induced radiative emission by atoms, a fairly complete discussion of the use of atoms as circuit elements is given. The concluding sections describe the actual application of masers to sensitive receiving systems.

24,615 MASERS IN SYSTEM APPLICATIONS by L.C. Morris (RCA); in Lasers-RCA, 1963, pp. 23-26; STAR, Vol. 2, p. 502(A), Feb. 23, 1964

Attention has been directed toward recent advances in maser development. This included the development of a traveling-wave maser; the construction of a small, compact maser utilizing rutile; the development of millimeter-wave masers; maser amplification at liquid-neon temperatures; and the application of masers in communications, such as in Telstar and Echo. The discussion also included maser noise temperature; antenna noise temperature; environmental noise sources; maser cooling systems; and future maser development.

24,616 DYNAMIC BEHAVIOR OF QUANTUM MECHANICAL OSCILLATORS by G. Makhov and O. Risgin (U. Michigan); Dec. 1963, 16 pp., Contract DA36 039sc78801; U.S. Gov. Res. Rep., Vol. 39, p. 15(A), Apr. 5, 1964 AD 427 186 OTS $1.60

The time variation of amplitude of a maser oscillator is derived from a study of the rate equations connecting the population inversion and the electromagnetic energy stored in the maser resonator. The methods of nonlinear mechanics are used to derive a qualitative description of the amplitude variation in the absence of a complete solution of the rate equations. Modifications of the simple rate equations necessary to account for the existence of undamped relaxation oscillations are introduced for both microwave and optical masers, and their physical significance is discussed. The production of 'giant pulses' of radiation is also treated.

24,617 PULSE SHARPENING AND GAIN SATURATION IN TRAVELING-WAVE MASERS by E.O. Schultz-Dubois (Bell Labs.); Bell Sys. Tech. J., Vol. 43, pp. 625-658, Mar. 1964

A pair of coupled nonlinear differential equations is given which describes the reduction of gain in a traveling-wave maser due to high-power signals. Integrals in closed form are obtained for two cases of interest. The first applies to pulsed optical amplifiers where no replacement of stored energy; i.e., the leading edge of an input pulse is amplified by the original full gain while later parts of the signal experience reduced gain. The second case is that of steady-state gain saturation in the presence of a continuous pumping process. The results describe the observed gain compression of microwave ruby traveling-wave masers.

24,618 RAMAN AND PHONON MASERS by R.Y. Chiao, E. Garmire and C. H. Townes (MIT); 1963, 29 pp., Lecture presented at Summer School Session of the Intern. School of Phys. "Enrico Fermi," Verenna, Italy, Aug. 1963, NASA Grant NsG-330; STAR, Vol. 2, p. 1046(A), Apr. 23, 1964 NASA CR-53103, OTS $2.60 ph, $1.07 mf

When the very intense beams of light generated by optical masers interact with matter, they tend to excite various degrees of freedom of both the matter and the radiation field, and sometimes such excitations are quite large. At certain threshold intensities, instabilities set in that transfer energy very rapidly from the beam to other electromagnetic or mechanical modes of the system. Some of these processes are discussed. The generation of coherent molecular oscillations or phonons by interaction between intense maser beams and matter is discussed in detail. The instabilities produce the observed intense Raman radiation along with coherent molecular vibrations. The possibility that they also lead generation of intense high-frequency sound waves and infrared radiation was also investigated.

24,619 EFFICIENCY OF A P-N DIODE LASER by A. Scott (U. Wisconsin); Proc. IEEE, Vol. 52, pp. 325-326(L), Mar. 1964

An expression for the outside differential quantum efficiency of a p-n diode laser (i.e., the ratio of an increase of the rate at which photons are emitted from the diode to the corresponding increase in the rate at which exciting electrons are crossing the junction) which is valid just above the threshold is derived. The diode structure is assumed to be a central active layer of complex conductivity $-\sigma_- + j\omega\epsilon$, bounded by two passive layers of complex conductivity $\sigma_+ + j\omega\epsilon$. The differential efficiency is found as a function of the threshold current and of the voltage reflection coefficient at the polished ohmic contact end faces.

24,620 ANALYSIS OF A GaAs LASER by J.R. Biard, W.N. Carr and B.S. Reed (Texas Instr.); Trans. Met. Soc. AIME, Vol. 230, pp. 286-290, Mar. 1964

An analysis of the semiconductor injection laser is presented which is based on a phenomenological model using device and material parameters. The intent of the laser threshold analysis is not to predict from theory the actual threshold current density but rather to provide a logical means of interpreting experimental results. The device and material parameters have been selected such that they describe both the threshold conditions and quantum efficiency of the laser. A technique is proposed whereby the current required to obtain a population inversion is predicted from device I-V characteristics. Experimental data are presented which support the analysis.

24,621 THE SPEED OF RESPONSE OF GaAs LASERS by C. Hilsum, D.J. Oliver and J.M. Tanner (SERL); Phys. Lett., Neth., Vol. 8, pp. 232-233(L), Feb. 15, 1964

Measurements of the time delay between the injection of forward current and the emission of stimulated radiation in a gallium arsenide laser at liquid nitrogen temperatures are reported. No measurable delay was observed with the circuit used. This result differs from that of Lytollis et al., who observed a delay of more than 100 nsec between the application of currents just above threshold and the appearance of stimulated radiation. Experiments were also performed with the circuit of Lytollis et al. These experiments indicated that the reported delays were not delays in the initiation of laser action, but were indications of degradation of the current pulse caused by the circuit arrangement.

24,622 SHIFTS OF MODE SPECTRA WITH CURRENT IN GaAs LASER by S. Seishi and T. Kushida (Tokyo Shibaura Electric); Japanese J. Appl. Phys., Vol. 3, pp. 162-163(L), Mar. 1964

The dependence of mode spectra on forward current in GaAs lasers is reported. A shift of mode lines to shorter wavelengths and movement of the center of the spectrum to longer wavelengths with increasing current at 77°K is noted. The rate of mode line shift is about 0.1 A/amp. The mechanism causing such shifts may be: (a) change of oscillating mode; (b) change of cavity resonance frequency; or (c) other mode pulling effects. The diode used in this study was prepared by diffusing Zn into n-type GaAs with an impurity concentration of $4.6 \times 10^{17}/cm^3$.

24,623 MODIFICATION OF THE NEAR-FIELD PATTERN OF A GaAs LASER BY A MAGNETIC FIELD by A.B. Fowler and E.J. Walker (IBM); J. Appl. Phys., Vol. 35, p. 727(L), Mar. 1964

Changes in the near-field patterns of GaAs lasers can be induced by a magnetic field. Such changes associate the mode jumping in GaAs lasers with the microscopic inhomogeneities that also result in the filamentary structure. Depending as they do on the exact nature of each junction these effects are not amenable to detailed analysis; it is pointed out that they should not be confused with more fundamental effects.

24,624 A NEW GaAs LASER THAT CAN BE PUMPED ELECTRICALLY by J.L. Pankove (RCA); in RCA, Camden N.J. Lasers, 1963, p. 28; STAR, Vol. 2, p. 502(A), Feb. 23, 1964

A very simple, electrically pumped, semiconductor laser comprised of a p-n junction diode in a wafer of gallium arsenide is described. The GaAs was converted into a laser by altering its shape, by decreasing the contact resistance reduce losses, and by increasing the current density through the junction.

aAs Diode Lasers - See 23,739

,625 PREPARATION AND PROPERTIES OF $Ga(As_{1-x}P_x)$ p-n JUNCTION ASERS by N. Holonyak, Jr. (U. Illinois); Trans. Met. Soc. AIME, Vol. 230, . 276-281, Mar. 1964

ilogen vapor-transport synthesis of $Ga(As_{1-x}P_x)$ and its preparation into laser nctions are described. Electrical and optical properties of $Ga(As_{1-x}P_x)$ laser nctions are discussed. The present limitations in these properties are related material problems and the very early state of development of $Ga(As_{1-x}P_x)$, d are discussed in this context. Inhomogeneity problems, fluctuation of As:P tio, and problems with deep-level contaminants are described and related to a$(As_{1-x}P_x)$ junction performance. Laser junctions are demonstrated which op-ate to wavelengths as short as 6470 A (77°K). The prospect that $Ga(As_{1-x}P_x)$ ll operate to wavelengths perhaps 100 A shorter is mentioned.

,626 HARMONIC GENERATION IN INJECTION LASERS by A.W. Smith, .I. Nathan, J.A. Armstrong, A.E. Michel and K. Weiser (IBM); J. Appl. ys., Vol. 35, pp. 733-734(L), Mar. 1964

early resolved mode structure has been observed in the fundamental and sec-nd-harmonic signals of GaAs injection lasers. Observation of second-harmonic eneration in InP injection lasers is also reported. In several GaAs lasers the ndamental was polarized perpendicular to the junction and the harmonic was olarized in the junction plane. The relative intensities observed for the blue odes were not always equal to the squares of the relative intensities of the rresponding red modes. A quadratic dependence of harmonic power on funda-ental power was observed for the InP laser.

,627 INDIUM PHOSPHIDE LASER CHARACTERISTICS by K. Weiser, R.S. itt, M.I. Nathan, G. Burns and J. Woodall (IBM Watson Res. Ctr.); Trans. et. Soc. AIME, Vol. 230, pp. 271-275, Mar. 1964

he preparation of InP diodes and their properties as injection lasers are de-ribed. Junctions were prepared by diffusing zinc into n-type material, and a udy was made of junction penetration as a function of zinc pressure and of me. Spontaneous and stimulated emission was studied in the temperature range om 2° to 300°K, and efficiency measurements were performed at 77°K. At e moment, InP lasers are comparable with but somewhat inferior in quality to aAs lasers.

4,628 InAs LASER CHARACTERISTICS by I. Melngailis (Lincoln Lab.); Bull. m. Phys. Soc., Vol. 9, p. 269(A), Mar. 1964

easurements of the absolute power output of InAs injection lasers have been ade using a calibrated thermopile. For the lasers examined, the external ef-iciency was lower than that reported for GaAs lasers. Besides reducing the reshold, a magnetic field of a few kilogauss applied transverse to the diode urrent also produces a substantial increase in the external efficiency of InAs sers. The spatial distribution of the coherent radiation has been determined, sing a photovoltaic InSb detector. In most lasers, a complex diffraction pat-rn with multiple high-intensity beams was observed, indicating the presence f multiple filaments in the laser.

4,629 InSb-DIODE-LASER THRESHOLD REDUCTION WITH A MAGNETIC IELD by R.J. Phelan, Jr. and R.H. Rediker (Lincoln Lab.); Bull. Am. Phys. oc., Vol. 9, p. 269(A), Mar. 1964

he spontaneous infrared emission from InSb diodes in magnetic fields has been tudied in an attempt to correlate the lineshapes and intensities with the thresh-ld for laser action. A grating spectrometer was used to obtain resolutions bet-er than 2×10^{-4} ev. Two spontaneous lines close to the bandgap have been ob-erved as a function of the diode current and magnetic field. The magnetic ield clearly intensifies both lines. A field of 30 kg narrowed a spontaneous mission line from 5×10^{-3} to 2×10^{-3} ev and increased the intensity by a factor f 50.

4,630 SILICON CARBIDE DIODE "LASER" by R.N. Hall (GE); in Semicond. evice Concepts, Oct. 31, 1963, pp. 47-58; STAR, Vol. 2, p. 624(A), Mar. , 1964 AD 426 258

uminescence from traveling solvent SiC diodes is discussed. It is concluded hat the narrow emission line which has been reported is due to the spontane-ous recombination of bound excitons and is unrelated to coherent light emission.

4,631 BIBLIOGRAPHY OF THE OPEN LITERATURE ON LASERS. Part II by E. Ashburn (Naval Ord. Test Sta.), B. Lengyel (Hughes Res. Labs.), and R. Merry (Lockheed); J. Optical Soc. Am., Vol. 54, pp. 135-142(L), Jan. 1964

A comprehensive listing of all material concerning lasers which appeared in open scientific literature before June 1963 is presented. A classification system for indexing laser information is also given; this system is of the Dewey Decimal type.

24,632 LASER TECHNOLOGY: AN ANNOTATED BIBLIOGRAPHY [Jan. 1962-Feb. 1963] by H.B. McCormick (Lockheed); Feb. 1963, 98 pp., SB-63-23; Rept. 5-73-63-6; STAR, Vol. 2, p. 919(A), Apr. 8, 1964

Advances in laser technology are reported against the background of comprehensive treatment of laser characteristics and action; new materials evidencing laser action; laser applications and problems; and the continuing research that is making such applications more practicable. Subject coverage is selective and representative rather than complete. The inclusion of recent bibliographies and evaluations (Section I: Bibliographies, and Section II: Laser Action and Applications) provides the reader the opportunity for more detailed background and perspective.

24,633 LASER MATERIALS: A TUTORIAL REVIEW WITH BIBLIOGRAPHY by J. E. Bradley (Ohio State U.); May 1, 1963, 298 pp., NASA Grant NsG-74-60; STAR, Vol. 2, p. 352(A), Feb. 8, 1964 NASA CR-52903; Rept. 1093-17, OTS $18.50 ph, $9.14 mf

A basic and tutorial paper, dealing with the nature of crystals and glasses, and to a lesser extent with some of the possible laser ions is presented. Also included is a bibliography, in part annotated, containing standard references and data sources as well as specific articles dealing with a variety of subjects related to crystals, glasses, spectra, and other subjects related to laser materials.

24,634 THE ANALYSIS OF LASER OPERATION FROM A MICROWAVE CIRCUIT VIEWPOINT by M.R. Wohlers (Grumman Aircraft); July 1963, 15 pp., RN-163; STAR, Vol. 2, p. 751(A), Mar. 23, 1964

The linear microwave-circuit theory of lasers is developed by ascribing the microscopic parameters μ and ϵ to lasing materials and then obtaining solutions to Maxwell's equations in the regions of interest. The approach is applied to a plane-wave Fabry-Perot interferometer filled with lasing material, and the threshold conditions for lasing or oscillation are determined. An example is presented which demonstrates the results as applied to a typical He-Ne laser.

24,635 THEORY OF PHONON-TERMINATED OPTICAL MASERS by D.E. McCumber (Bell Labs.); Phys. Rev., Vol. 134A, pp. A299-306, Apr. 20, 1964

A simple dielectric theory is used to describe the operating properties of phonon-terminated masers of the type reported by Johnson, Dietz, and Guggenheim. Basic to this model is a broadband gain characteristic which describes the frequency-dependent gain of the active maser material as a function of the populations of metastable electronic levels and of the temperature or temperatures describing lattice vibrations. The power levels required to produce phonon saturation are estimated to be extremely high (typically, $\sim 10^{10}$ W/cm^2 power output). Because phonon saturation does not ordinarily occur, a single-lattice temperature is generally sufficient. In that case, details of the electron-phonon coupling are unimportant, and the gain can be related by detailed balance to fluorescence and absorption spectra. Effects of phonon saturation are briefly discussed in the event that they might pertain to exceptional systems and because they give insight into the principles of operation of these masers.

24,636 PHOTON AVALANCHES FROM A POPULATION INVERSION by L. Tonks (GE); J. Appl. Phys., Vol. 35, pp. 1134-1141, Apr. 1964

High-power lasers encounter increasing losses of stored energy from stimulated emission by once-through avalanches of photons as higher powers are sought. This occurs even without resonance buildup. Even in the simple geometry of a thin rod, a satisfactory analysis would require elaborate machine calculation. A very crude model has, however, produced rough results from which some guidance is obtainable. The model exhibits the expected linear increase of outgoing photon flux near the end of the rod and the huge depletion of excited atom population away from the rod equator. A criterion has been developed for the maximum useful excitation relative to emission parameters, rod length and rod cross section. It is concluded that this excitation level is fairly insensitive to aspect ratio (radius/length) but that internal reflection from the rod cylindrical surface can markedly lower this level by increasing the effective aspect ratio enormously.

24,637 DYNAMICS OF THE GIANT PULSE LASER by L.M. Frantz (Space Tech. Labs.); Appl. Optics, Vol. 3, pp. 417-420, Mar. 1964

The time dependent behavior of the radiation buildup in a giant pulse laser is described analytically, neglecting cavity losses. Expressions are derived for the photon density as a function of time, and for the delay time and the rise time of the radiation pulse. The curve of radiant energy density vs time is plotted for several representative values of the parameters involved.

24,638 ELECTRONIC AND MUTUAL COMPONENTS OF STIMULATED EMISSION IN LASERS by G.F. Lewin (Brunel Coll., London); J. Electronics and Control, Vol. 16, pp. 21-28, Jan. 1964

The perturbation energy between the magnetic field of incident electromagnetic radiation and a laser electron is evaluated and shown to be small. A wave-mechanical treatment of laser action is given for the electric field perturbation,

and from this an expression is obtained for the emission or negative absorption coefficient which is in agreement with the calculation of Karplus and Schwinger (1948), based on matrix mechanics. Evaluation of this component for the $n = 2$, $l = 1$, $m = 0$ and $n = 3$, $l = 0$, $m = 0$ levels of a hydrogen-like atom leads to a simple relation between emission coefficient and wavelength.

24,639 PULSED LASER BEAM PICTURES by R. Jeanes, Jr. (Tufts U.); Appl. Optics, Vol. 3, p. 318(L), Feb. 1964

A quick and simple method for defining the size and location of a laser beam is described. When a piece of ordinary carbon paper is placed in a beam, the surface coating is evaporated and leaves an accurate representation of the cross-section of the beam. This may be used in aligning a laser with bolometers or comparable equipment

24,640 SIGNAL DETECTION WITH A LASER AMPLIFIER by H.A. Steinberg (Tech. Res. Gp., Syosset); Proc. IEEE, Vol. 52, pp. 28-32, Jan. 1964

The use of signal-to-noise ratio as a figure of merit for a signal detection system involving a threshold detector may lead to erroneous conclusions when the signal strength, in absolute terms, is small. Recourse to approximate or exact distributions must be made and the notion of statistical separation must be employed. A new figure of merit utilizing the idea of statistical separationis defined. The method is applied to the question of the efficiency of a laser amplifier in a pulse detection system.

24,641 CONSIDERATIONS OF NOISE AND SCHEMES FOR ITS REDUCTION IN LASER AMPLIFIERS by H. Kogelnik and A. Yariv (Bell Labs.); Proc. IEEE, Vol. 52, pp. 165-172, Feb. 1964

Spontaneous emission adds noise to the signal in laser amplifiers. The radiation characteristics of this noise and structures to reduce it are discussed. The structures make use of the spatial directionality of coherent light, and consist of aperture stops in combination with lenses. Their ultimate performance is studied. Signal-beam configurations necessary for optimum signal-to-noise (SNR) are described.

24,642 FIVE LAYER OPTICAL MASER AMPLIFICATION by H. Jacobs, D. Holmes, F.A. Brand and L. Hatkin; IEEE Trans., Vol. MTT-12, pp. 163-170, Mar. 1964

The optical maser is treated in the manner of a Fabry-Perot resonator with an active medium. Five layers are considered: air, reflector, active medium (ruby), reflector, and air. General equations are derived using the method of boundary value problems in which it is assumed that incident coherent radiation falls normally on the surface. It is suggested that the presence of lossless one-quarter wavelength reflectors will enhance the amplification of the device in that less pumping may be required for a given length of ruby. The role of the reflectors in oscillation conditions is shown to be of importance. Methods are indicated for the calculation of amplitude and phase for an idealized amplifier.

24,643 THERMAL EFFECTS IN LASER AMPLIFIERS AND OSCILLATORS by A. E. Blume and K.F. Tittel (GE); Appl. Optics, Vol. 3, pp. 527-530, Apr. 1964

The causes and implications of thermally induced optical effects in solid-state laser materials are discussed. A convenient interferometric method is described for examining in a typical helical and linear laser configuration the transient optical phenomena produced by thermal expansion, change of refractive index with temperature and strain. The results obtained with a neodymium laser glass rod are presented photographically.

24,644 DEVELOPMENT OF EFFECTIVE LASERS by L.A. Murray, M.F. Lamorte and F.L. Vogel (RCA); in Lasers, RCA, Camden, N.J., 1963, pp. 8-11; STAR, Vol. 2, p. 501(A), Feb. 23, 1964

Effort has been devoted toward minimizing strain and impurities in grown laser crystals. Described are the effects on laser performance of the polish, parallelism, and reflecting surfaces of the prepared laser rod and the geometry of the pumping system, as well as the construction of absolute and relative threshold measurement apparatus.

24,645 PERIODIC LASER OSCILLATIONS FROM ULTRASONICALLY VIBRATED RUBY ROD by N. Tsuya (U.S. Naval Ord. Lab.), F. Inaba, S. Kainuma, T. Torada and T. Sato (Tohoku U.); Bull. Am. Phys. Soc., Vol. 9, p. 281(A), Mar. 1964

Periodic giant spikes of laser emission from an ultrasonically vibrated ruby rod have been observed. The effects of transverse as well as longitudinal mechanical modes of vibration were examined. The excitation, at up to about 100 kcps, was transmitted by steel exponential horns attached to magnetostrictively excited Ni-Cu-Co ferrite transducers. In this experiment, regularly separated series of giant pulses of laser emission from the ruby crystal during pumping by an xenon flash was observed. Upon application of either the longitudinal or transverse ultrasonic vibrations, a higher peak-power output was found that is dependent on the amplitude of the ultrasonic waves, a shorter rise time of the output pulses, and narrower pulse durations. The enhancement of the observed output spikes is comparable with those reported using the known Q-spoiling methods. During the transverse vibration, two output pulses per ultrasonic period were detected. Under the longitudinal modulation, only one output pulse per ultrasonic period occurs. Increasing the amplitude of the longitudinal vibration still results in a single pulse per period.

24,646 GROUND-STATE POPULATION IN AN OPERATING PULSED RUBY LASER by R.L. Aagard and R.A. Dufault (Minn.-Honeywell); Appl. Phys. Lett., Vol. 4, pp. 102-104(L), Mar. 15, 1964

Measurements of the fractional ground state population in an operating pulsed ruby laser are reported. With the ruby laser rod at room temperature, light transmitted along the axis of the laser was measured throughout the spectral region from 4800 to 6200 A in both the operating and the unpumped conditions. Typical data reduced to the absorption coefficient for both conditions are given, together with the ratio of these coefficients α/α_0. Since the absorption coefficient is the product of the absorption cross section and the ground state population, α/α_0 is a measure of the fractional ground state population. For the crystal measured, at room temperature and without apertures at the crystal face, the population was 46±3 per cent. The ground state population measured at 145°K, 200°K, and 300°K agree with the theoretical model for the ruby laser proposed by Nelson and Remeika.

24,647 ELECTRON-EXCITED PHOSPHOR-LASER PUMPING by J.W. Oglanc, C.W. Baugh and W.E. Horn (Westinghouse); Bull. Am. Phys. Soc., Vol. 9, p. 270(A), Mar. 1964

Laser operation has been achieved using an electron beam that excites a phosphor that, in turn, pumped the $CaWO_4:Nd^{3+}$ laser crystal. A concentric arrangement of the phosphor around the laser crystal was excited by electrons from 4 thermionic emitters. The phosphor is ZnCdS:Ag, which has been modified to raise the current-saturation level and more closely match the absorption of the laser material at 5800 A. The fraction of the phosphor optical energy absorbed in the laser rod is discussed as a function of the phosphor reflectivity, laser-rod surface area, phosphor surface area, and the laser-rod absorption and index of refraction. The threshold energy density on the phosphor produced by the electron beam is about 2.5 kW/cm^2, which had a pumping pulse duration of 100 μsec. Repetitive operation was achieved at rates up to 20/sec with this initial arrangement.

24,648 SUN-PUMPED CONTINUOUS LASER by R.C. Duncan, Jr., Z.J. Kiss and H.R. Lewis (RCA); in Lasers, RCA, Camden, N.J., 1963, p. 27, Contract AF 33(616)-8199; STAR, Vol. 2, p. 502(A), Feb. 23, 1964

Laser action has been achieved in a $CaF_2:Dy^{2+}$ system at liquid-neon temperature (27°K) using the sun as the pumping source. This laser action in the $CaF:Dy^{2+}$ system was reported at 2.36 microns. The low pulsed laser threshold, the long lifetime, and the convenient location of the broad pumping bands of this system make it especially suitable for sun-pumped operation.

24,649 CONTINUOUSLY PUMPED SOLID STATE OPTICAL MASERS by W.S. Boyle and D.F. Nelson (Bell Labs.); in Light and Heat Sensing, AGARD, Paris, 1963, pp. 199-206; STAR, Vol. 2, p. 917(A), Apr. 8, 1964

The chromium-doped aluminum oxide (ruby) and neodymium-doped calcium tungstate solid-state masers, are examined. A comparison is made between two different pumping geometries; the importance of the spectroscopic properties of maser crystals in determining the pumping requirements is illustrated.

Pulse/Amplitude Modulated Ruby Lasers - See 24,389

24,650 OPTICAL HETERODYNING USING POINT CONTACT GERMANIUM DIODES by C. Patel and W. Sharpless (Bell Labs.); Proc. IEEE, Vol. 52, pp. 107-108(L), Jan. 1964

Photobeats have been obtained at several microwave frequencies in the region of 14 kMc/sec and 17.7 kMc/sec using a point contact germanium diode. The microwave signals were the result of heterodyne detection of the optical power output from a bromine-argon maser with the diode. The diode was electrochemically etched to obtain a short transit time for photoelectrons and mounted across a rectangular Ku-band waveguide at the center to excite a TE_{10} mode in the guide when a microwave frequency current was generated in the diode. A full discussion of the experimental technique, results, and theoretical correlation is presented. In particular, the beats in the 14 kMc region were spectrographically predicted to be at 13.92 kMc/sec which is in good agreement with the measured value of 13.98 kMc/sec.

24,651 OPTICAL HETERODYNE DETECTION OF MICROWAVE-MODULATED LIGHT by R. Targ (Sylvania); Proc. IEEE, Vol. 52, pp. 303-304(L), Mar. 1964

The demodulation of microwave-modulated light by optical heterodyne techniques is described. These techniques are utilized for the automatic frequency

ontrol of a laser local oscillator. This AFC method uses single-sideband suppressed-carrier modulation, where the all-quartz 6328 A laser local oscillator is offset by a variable microwave frequency which is adjusted to compensate for the time-varying frequency of the incoming laser signal carrier. The experimental arrangement now provides automatic frequency control to lock the local oscillator frequency a specified microwave difference frequency from the signal, despite frequency drifts of either laser.

4,652 A MEANS OF AIMING A LASER BEAM by L.W. Nichols (Naval Ord. Test Sta.); Jan. 1964, 4 pp., NOTS TP3446; NAVWEPS 8481; U.S. Gov. Res. Rep., Vol. 39, p. 136(A), Apr. 20, 1964 AD 429 341 OTS $1.10

The retrodirective reflecting properties of a corner reflector can be used to aim a laser beam. When portions of a corner reflector are placed in front of a laser and its aiming telescope, then an image of the laser beam is superimposed on the telescope image to show the exact target area being illuminated by the beam.

4,653 COHERENT OPTICAL BEAM STEERING TECHNIQUES by L.W. Propio, F.A. Jessen, P.M. Nave and L.J. Brown (Philco); Jan. 1964, 103 pp., Contract AF30 602 290; U.S. Gov. Res. Rep., Vol. 39, pp. 117-118(A), Apr. 0, 1964 AD 428 203 OTS $9.60

The technical problems involved in achieving an electronically scanned coherent optical phased array are examined in detail. Background information pertinent to an array design, including studies of coherent optical components, optical losses, limitations imposed by propagation effects, and radiation patterns generated by laser elements is presented. Techniques to achieve both electronic steering of a single laser beam and a phased array of lasers are analyzed. Studies include consideration of the physical devices themselves, and analysis of their environmental sensitivity, radiation characteristics, and response speeds. Design investigation of the optical phased array includes analysis of the the laser oscillator-amplifier combination, the electronically controlled optical phase shifters, the element beam steering devices, and the output telescope systems. Typical design data and performance specifications are presented.

4,654 DOUBLE RESONANCE OF INVERTED TWO-LEVEL SYSTEM by I.R. enitzky (U.S. Army Labs.); Bull. Am. Phys. Soc., Vol. 9, p. 280(A), Mar. 1964

The experiment of Johnson et al. (Phys. Rev. Lett., Vol. 7, p. 318, 1963) involving optical-maser oscillation at a frequency less than that corresponding to the pertinent atomic-level separation - the difference frequency appearing in the phonon field - was given a different interpretation from that offered by the experimenters. It was suggested that the effect is due to a double-quantum process of a 2-level system with inverted population. The theory of such a process for a magnetic dipole was presented as a solution of the Bloch equations with two driving fields of frequencies ω_1 and ω_2, where $\omega_1+\omega_2 = \omega$, the resonant 2-level frequency. It was pointed out that if oscillation at ω can be prevented, then (nonacoustical) applications of this process include (1) pumping at ω_1 to produce oscillation at ω_2, (2) oscillation at both ω_1 and ω_2, (3) detection at ω_1 by the gain at ω_2, and (4) amplification at $1/2\ \omega$.

4,655 INVESTIGATION OF RELAXATION OSCILLATIONS IN THE OUTPUT FROM A RUBY LASER by D.D. Bhawalkar, W.A. Gambling and R.C. mith (U. Southhampton); J. Brit. IRE, Vol. 27, pp. 285-291, Apr. 1964

Measurements have been made on the 'spike' pulses produced by the relaxation oscillation in the output from a laser using a 90 deg ruby crystal. Pulse shape, width and height, the time interval between successive pulses, and the polarization of the pulses have been accurately measured. The rate equations describing the laser oscillation have been solved for operation of the laser close to threshold. The solution predicts a shape for individual pulses of the form $\cosh^{-2} K(t - t_0)$ and this has been verified by the experiments. It is well known that the ruby laser operates in narrow 'filaments'. The solution to the rate equations enabled the diameter and population inversion of the contributing filament to be obtained. Also the measurements on the pulse interval gave the number of filaments active in the crystal at a given time. All the pulses were found to be equally linearly polarized to 99.92 per cent.

4,656 MULTIMODE OSCILLATION OF THE RUBY LASER NEAR THRESHOLD by M. Birnbaum and T.L. Stocker (Aerospace Corp.); in Electron Res. Program -Opt. Maser Studies, Nov. 25, 1963, pp. 12-22; STAR, Vol. 2, p. 624(A), Mar. 8, 1964 TDR-169(3250-22)

Experimental results were obtained demonstrating that many axial modes are present in the output of a ruby laser which is operated very close to threshold. Multimode operation was found to be the rule, even when the output of the laser appeared as a regularly spaced, exponentially damped series of spikes. Theoretical analysis of the laser oscillations indicates that the initial laser spike transient should damp out, leaving only the CW (continuous wave) oscillation of the laser. This effect was observed in a ruby laser operated close to threshold. In many cases, the initial train of laser pulses appeared to damp out and approach a CW level of oscillation. A CW beat frequency was often found to coincide with the CW light output.

24,657 THE BEHAVIORS OF SPIKES OF A Q VARYING RUBY LASER by T. Yamanaka and C. Yamanaka (Osaka U.); Japanese J. Appl. Phys., Vol. 3, pp. 168-169(L), Mar. 1964

The behavior of spikes of a Q varying ruby laser is studied. The laser rod was aligned between two separately mounted flat multidielectric-layer reflectors. A Faraday rotator was placed between one of the reflectors and the ruby rod. A single pulse of very high intensity is obtained if the onset of stimulated emission is delayed by Q spoiling until excitation reaches far above the threshold. If the magnetic field of the Faraday rotator is varied sinusoidally, spikes are observed only at instances of zero field, and definite patterns of series of spikes appear.

24,658 REGULAR AND IRREGULAR SPIKING IN A MULTIMODE SPHERICAL RUBY LASER by M. Katzman and J.W. Strozyk (USAERDL); J. Appl. Phys., Vol. 35, pp. 725-727, Mar. 1964

Regular spiking in a multimode cavity is confirmed. It was produced at input energies varying from close to threshold to 40 per cent above threshold. A decrease in the number of off-axis modes makes the spiking irregular.

24,659 THE RELATION BETWEEN THE SPIKES AND THE Q SPOILING TIME IN A RUBY LASER by C. Yamanaka and T. Yamanaka (Osaka U.); Japanese J. Appl. Phys., Vol. 3, pp. 231-232(L), Apr. 1964

The relation between spike height and the Q spoiling time has been investigated on a 60° cut ruby. Induced emission was quenched after 150 μsec from the initiation of laser action. The duration of the Q spoiling time was varied from 17 to 60 μsec. τ (relaxation time) and θ_∞ (peak photon density at saturation) were estimated from the experimental data. The normalized peak photon density (or spike height) is calculated from the relation: $\theta/\theta_\infty = (1 - \exp(-t_s/\tau)$ where t_s is Q spoiling time. A plot of spike height vs Q spoiling time is presented.

24,660 SEARCH FOR A STOKES SHIFT IN THE R_1 LINE OF RUBY by J.W. Brault, P.J. Warter, Jr., and R.U. Martinelli (Princeton U.); Bull. Am. Phys. Soc., Vol. 9, p. 281(A), Mar. 1964

Virtually simultaneous measurements of the emission and absorption profiles of the ruby R_1 line show that no significant Stokes shift is present. Observations were made on samples of 0.006 per cent and 0.02 per cent Cr by weight in the temperature range from 77° to 153°K. The position of the peaks in the absorption line matched those of the emission line to within 0.002 cm^{-1}. Shifts this size or smaller will cause no significant change in the operating characteristics of a laser.

24,661 LASER CHARACTERISTICS AND SOME POTENTIAL APPLICATIONS by D. Karlsons and D.J. Parker (RCA); in Lasers, RCA, Camden, N.J., 1963, pp. 20-22; STAR, Vol. 2, p. 501(A), Feb. 23, 1964

Favorable and unfavorable laser characteristics that affect applications, current trends and needs in laser equipment development, and potential laser applications are discussed. The ability to realize very small angular beamwidths in the optical region is the prime parameter of almost every application proposed for the laser, giving it the property of extremely efficient power transfer over long ranges. Small wavelengths associated with lasers mean that small oscillating structures can serve as relatively high-gain antennas for radiating their energy. High noise temperatures, very difficult propagation characteristics for application through the earth's atmosphere, and rather poor efficiencies are all disadvantages of the laser. Some of the applications of the laser are as amplifiers; as a power generator capable of very-high-peak outputs; as well as average power levels; as detectors; in communication systems; and in radar systems.

24,662 LASER ACTION IN A FLUX-GROWN RUBY by D.F. Nelson and J.P. Remeika (Bell Labs.); J. Appl. Phys., Vol. 35, pp. 522-529, Mar. 1964

A method of growing very perfect ruby crystals by slow cooling of a $PbO(B_2O_3)x$ flux doped with Al_2O_3 and Cr_2O_3 is described. A crystal grown by this method has been operated as a laser with its natural crystal faces used as feedback surfaces. Interferometry through these surfaces showed that the optical path length between the feedback faces varied only about $\lambda/10$ for red light over the entire face. The angles of laser emission high above threshold agreed accurately with those predicted for a Fabry-Perot cavity. Near threshold the output consisted of a very regular damped oscillation of the Statz-deMars type that was completely linearly polarized. A little farther above threshold a second train of oscillations was also present and was polarized at 90° to the first train. A formula for the laser threshold dependence on temperature was derived. A comparison of the model with measurements made between 90° and 305°K allowed a determination of the cavity loss under laser operation. With multilayer dielectric film reflectors a loss of less than 1 per cent per pass was found, the

bulk of which could be accounted for by known transmission and absorption losses in the end films.

24,663 EFFECT OF DIFFRACTION ON THE OUTPUT BEAM OF A RUBY LASER by M. Birnbaum and T.L. Stocker (Aerospace Corp.); in Electron. Res. Program – Opt. Maser Studies, Nov. 25, 1963, pp. 1-11; STAR, Vol. 2, p. 624(A), Mar. 8, 1964 TDR-169(3250-22)

Observations were made of the near-field and far-field patterns of a ruby laser operated near threshold. In these observations, the beam diffraction effect predicted for diffraction by a small, elliptically shaped aperture was observed. This effect was a 90-degree rotation of the elliptical figure. The beam divergence was greater than that predicted using diffraction theory.

24,664 RESEARCH ON LASER MATERIALS by P.G. Herkart, M. Kestigian and P.N. Yocom (RCA); in Laser, RCA, Camden, N.J., 1963, pp. 4-7, Contract AF33(616)8199; STAR, Vol. 2, p. 501(A), Feb. 23, 1964

The importance of the proper choice of materials for laser operation was emphasized because continuous operation, heat dissipation, and operating frequency are all functions of this parameter. Several criteria are given which laser materials must fulfill, and the steps involved in the preparation of laser materials are discussed. Some of the materials utilized in lasers are given, and other materials which have possible use are mentioned.

24,665 LASERS AND SEMICONDUCTORS [in French] by M.G.A. Bernard and G. Duraffourg (Ctr. Natl. d'Etudes des Telecommun.); in Light and Heat Sensing, AGARD, Paris, 1963, pp. 185-191; STAR, Vol. 2, p. 917(A), Apr. 8, 1964

The possibility of obtaining from semiconductors emissions stimulated by the transitions between the conduction bands and the valence bands, between one of these bands and an impurity level of the interdictive band, or by annihilation excitation is discussed. If the state of occupation of these bands and the levels are characterized by the pseudolevels of Fermi, the condition necessary for a stimulated emission is $\Delta F > h\nu$, where ΔF is the difference between the pseudolevels of Fermi of the initial state and the final state of the transition, and $h\nu$ is the energy of the induced photon. The direct transitions from band to band in InAs and InSb and the transitions between the bands of conduction and the acceptor levels of Zn and In, respectively, in Ge and Si are presented. An analysis is made of the various causes of loss, and the particular cases in which conditions for obtaining the laser effect can be realized are discussed.

24,666 LASER ACTION IN NEODYMIUM-DOPED GLASS AT 1.37 MICRONS by P. Mauer (Eastman Kodak); Appl. Optics, Vol. 3, p. 153(L), Jan. 1964

Laser action in the $4F_{3/2} \rightarrow 4I_{13/2}$ transition of Nd^{3+} ions at room temperature is reported. Power input to the 6.35 mm diameter, 5.1 cm long, 1 per cent weight Nd_2O_3 in La-Ba-Th-borate glass rod was 6.35 J. Output was at 137 μ. It is postulated that laser action would have occurred at 1.33 μ if the reflectance peak of the coating had coincided with the fluorescence peak.

24,667 GLASS LASER RESEARCH by T.C. MacAvoy, M.L. Charters, R.D. Maurer, W.H. Dumbaugh and N.F. Borrelli (Corning Glass); June 28, 1963, 128 pp., Contract Nonr383300; U.S. Gov. Res. Rep., Vol. 39, p. 131(A), Apr. 20, 1964 AD 429 010 OTS $10.50

A study of the spectral properties of Nd-doped glasses was undertaken with the objects of (1) determining how the properties of glass influence the performance of an Nd-doped glass laser, and (2) developing the best possible glasses for high power applications. The work consists of an extensive study of a wide variety of different glass compositions in parallel with a detailed study of the spectral properties of one glass. Emphasis was on silicate glasses, which show the longest lifetimes and most intense fluorescence. Borates show the shortest lifetimes and weakest fluorescence. Since oscillator strengths are about equal for all glasses studied, the borates are apparently quenched. Certain impurities such as Fe, Cu and Ni quench the Nd fluorescence.

24,668 OPTICAL MASER OSCILLATIONS FROM Ni^{2+} IN MgF_2 INVOLVING SIMULTANEOUS EMISSION OF PHONONS by L.F. Johnson, R.E. Dietz and H.J. Guggenheim (Bell Labs.); Phys. Rev. Lett., Vol. 11, pp. 318-320(L), Oct. 1, 1963

Observations of fluorescence from Ni^{2+} in MgF_2 and optical maser oscillation in a line which involves transitions between electronic states of Ni^{2+} and simultaneous vibrational excitations of the MgF_2 lattice are reported. Energy levels are deduced from the spectroscopic data for both the fluorescence spectra and the phonon energy. The phonon energy is explained by a transition at 340 cm^{-1} of the crystal as a whole.

24,669 STIMULATED EMISSION FROM $Y_2O_3:Nd^{3+}$ by R.H. Hoskins and B.H. Soffer (Korad); Appl. Phys. Lett., Vol. 4, pp. 22-23(L), Jan. 1, 1964

Fluorescence spectra at 300°K and 77°K and stimulated emission at 77°K in $Y_2O_3:Nd^{3+}$ are discussed. The halfwidths of the most intense fluorescence lines were 10 cm^{-1} at 300°K and 3.8 cm^{-1} at 77°K. The lines shifted to higher frequencies by ~16 cm^{-1} upon cooling to 77°K. Lines observed at 9495, 9459, and 9125 cm^{-1} at 300°K disappeared at 77°K. The 300°K and 77°K fluorescence lifetimes were both ~260 μsec. For the stimulated emission experiments a crystal 2mm in length and 2 mm in diameter, containing approximately one atom per cent of Nd^{3+} was fabricated into an optically parallel cylinder. The ends were coated with a dielectric multilayer with a high reflectance at wavelengths between 1.06 and 1.09 μ. Stimulated emission was observed at 1.073 μ and 1.078 μ, but not at 1.103 μ. Threshold for the 1.073 μ radiation was ~260 J; for the 1.078 μ line ~350 J.

ASSOCIATED DEVICES

24,670 TORSION PENDULUM PHOTOMETER by M. Stimler, Z.I. Slawsky and R.E. Grantham (U.S. Naval Ord. Lab.); Rev. Sci. Instr., Vol. 35, pp. 311-313, Mar. 1964

An instrument is described for making fundamental measurements of high energies of pulsed laser beams. The principle of operation is the transfer of beam-photon momentum to angular momentum of a double-reflecting ballistic torsional pendulum. The operating pressure is below 5×10^{-5} mm Hg. The sensitivity, 2.55 ± 0.04 cm/J, and damping of initial oscillations before making a measurement is not required. In addition to providing the capability of simultaneous energy measurement and use of a laser beam, the measurements made with this instrument appear to be more accurate than with a commercial calorimeter used for comparison.

24,671 CALCULATIONS ON FABRY-PEROT LASER RESONATORS WITH SCATTERING MATRIX [in German] by D. Gloge (Tech. Hoch., Braunschweig); Arch. Elek. Uebertragung, Vol. 18, pp. 197-203, Mar. 1964

Fabry-Perot resonators not only play an important role in the realization of lasers, but also from their behavior valuable conclusions may be drawn concerning the properties of light transmission lines with periodic focussing elements. In this paper a perturbation method of analysis is developed which takes into consideration systematic imperfections that occur in practical mirrors and lenses. To demonstrate the efficiency of this method, it is applied to resonators with mirrors of arbitrary radii of curvature, by treating them as perturbed confocal resonators with known properties. In this way one obtains the diffraction losses of arbitrary resonators with satisfactory accuracy. The accuracy improves with increasing diffraction losses. The perturbation analysis is then generalized for more complicated systems with focussing elements at arbitrary intervals and with arbitrary apertures. Finally, a reduction scheme is given for lenses with sufficiently large apertures.

24,672 RUBY LASER WITH MODE-SELECTIVE ETALON REFLECTOR by D. Roess (Siemens and Halske); Proc. IEEE, Vol. 52, pp. 196-197(L), Feb. 1964

A simple plane dielectric mirror-plane parallel dielectric etalon resonator which allows for the selection of single modes in ruby lasers is described. The reflectivity of the etalon is chosen in such a way that, with the given pumping energy, temperature and length of the inverse material, oscillation threshold is reached only by those modes that are reflected in phase at both sides of the etalon. The selected modes are the modes of the etalon itself. Near the threshold energy only one mode of oscillation was observed. At high pumping energies the emission was no longer restricted to one mode.

24,673 DESIGN AND FABRICATION OF OPTICAL FILTERS FOR LASER FREQUENCY by S.J. Holmes and N. Bowman (Spectrolab.); Aug. 29, 1963, 12 pp., Contract AF33 657 9216; U.S. Gov. Res. Rep., Vol. 39, p. 64(A), Mar. 5, 1964 AD 419 554 OTS $1.60

24,674 SPECTRAL CHARACTERISTICS FOR A NEODYMIUM LASER LIQUID FILTER SYSTEM by K.F. Tittel (Adv. Tech. Lab., GE); Rev. Sci. Instr., Vol. 35, pp. 522-524, Apr. 1964

The spectral transmissions of several liquids are described, and an optimum liquid filter for neodymium laser materials is determined. The work showed that either a weak acidified solution of copper chloride or an aqueous solution of potassium chromate or sodium nitrite provides the optimum transmission characteristics as effective filters for an optically pumped neodymium laser system. The last two solutions were found best for ultraviolet sensitive host materials.

24,675 DESIGN AND FABRICATION OF OPTICAL FILTERS FOR LASER FREQUENCY by S.J. Holmes and N. Bowman (Spectrolab.); Dec. 3, 1963, 26 pp., Contract AF33 657 9216; U.S. Gov. Res. Rep., Vol. 39, p. 57(A), Apr. 5, 1964 AD 427 005 OTS $2.60

The application of mica as a laser material is discussed. Indian pale green mica is reported to have the highest transmission coefficient for any natural mica. Using the measured optical properties of this mica, calculations were made to determine the optimum filter configuration. For the experimental filters, mica

lf-wave plates coated on both sides with five alternate layers of zinc sulfide d cryolite have been used. The theoretical bandwidth of this type of filter nfiguration is 0.8 A, and the expected transmission is in the order of 75 per nt without any auxiliary filtering. For a filter employing reflecting stacks of s layers the transmission is higher but the rejection of the background outside e passband is much less.

,676 WIDEBAND MICROWAVE PHOTOTUBES FOR LASER COMMUNICA-ONS SYSTEMS by D.J. Blattner, H.C. Johnson, F. Sterzer and J.E. Reudy CA); in Lasers, RCA, Camden, N.J., 1963, pp. 27-28, Contract DA 36-039--90846; STAR, Vol. 2, p. 502(A), Feb. 23, 1964

e RCA developmental A-1283 microwave phototube is schematically diagram-, and its operation is described. The light to be modulated passes through the tical window onto a transmission type photocathode. The photoelectrons emit-d by the cathode are bunched at the modulation frequency of the light. As se electrons pass through a traveling-wave-tube type helix, they excite a veling wave that is taken out at the output coupler. The tube with its focus-g periodic permanent magnets is 18 inches long and weighs 5 pounds.

,677 MODULATORS AND DEMODULATORS FOR LASER SYSTEMS by D.J. ttner and F. Sterzer (RCA); in Lasers, RCA, Camden, N.J., 1963, pp. 12-, Contract AF 33(616)-8199 and DA 36-039-SC-90846; STAR, Vol. 2, p. 1(A), Feb. 23, 1964

deband laser modulators that utilize crystals exhibiting linear electro-optic fects are under investigation, and work is being conducted on special micro-ve phototubes capable of demodulating light that has been modulated at gig-lycle rates. Some of the techniques and some of the materials utilized in the stems are given.

ptical Modulators - See 24,447 and 24,611-24,613

ser Beat Detecting Photodiodes - See 24,606

,678 PULSE POWER SUPPLY DESIGN FOR LASER PUMPING by S.J. Grab-ski (GE); Electronics, Vol. 36, pp. 33-35, Dec. 20, 1963

e design of a pulse-forming modulator for flash lamp laser-pumping employ-g a constant-current network with voltage limiting and thyratron tube trigger-g is described. Constant-current networks used in laser pumping require volt-e limiting to prevent component destruction during zero-load periods. Con-nt current is supplied by a network of reactive components and voltage lim-d by two silicon controlled rectifiers switched by a Zener diode which is pre-t for maximum voltage. A voltage step-up rectifier transformer with silicon gle-phase bridge rectifier stacks supplies power from constant current net-rk to a pulse-forming network consisting of a network coil and capacitor bank. high power ceramic hydrogen thyratron with conventional triggering performs dulator switching and a saturating core trigger transformer is used to super-pose a high-voltage spike on the main flash tube triggering pulse.

APPLICATIONS

aser Applications in Communications Systems - See 24,788

ser Applications in:
- Ranging:
  - and Communications Systems - See 24,789
  - Systems - See 24,789 and 24,791
- Scattering of Gases - See 24,857
- Breakdown in Gases - See 24,856
- Plasma Physics - See 24,855
- Optical Computers - See 24,792
- Medicine - See 24,854
- Metal Working - See 24,853

aser Display Systems - See 24,822

BASIC SOLID STATE DEVICE CIRCUITS

GENERAL

NETWORK THEORY

4,679 ON THE CONSTRUCTION OF A NETWORK FUNCTION FROM ITS PECIFIED EVEN PART by N. DeClaris and S. Mitra (Cornell U.); Proc. IEEE, ol. 52, p. 302(L), Mar. 1964

A method of constructing the total network function from the given even part is described. A network function of the form $Z(s) = (m_1+n_1)/(m_2+n_2)$ is assumed such that m_1 and n_1 have a common factor a(s), and m_2 and n_2 have a common factor b(s). The even part of such a function, $Ev\,Z(s) = P(s)/Q(s)$. Taking the partial fraction expansion of $P(s)/m_2n_2$ as equal to $m'_1/n'_2 - n'_1/m'_2$, it is then shown that the factors corresponding to a(s) and b(s) will have zero residues. In order to obtain the correct solution, multiply m'_1 by a(s) and n'_1 by b(s), and then add to get the appropriate numerator of the desired Z(s). In some cases it may be computationally simpler to obtain either m_1/n_2 or n_1/m_2 depending on convenience. The remaining function is then obtained by proper algebraic manipulation of the partial fraction expansion of $P(s)/m_2n_2$.

24,680 THE USE OF JACOBIAN ELLIPTIC FUNCTIONS IN THE ANALYSIS OF A NONLINEAR CIRCUIT by A.C. Soudack (U. Brit. Columbia); IEEE Trans., Vol. CT-11, pp. 118-122, Mar. 1964

A method for finding an approximate solution to $\ddot{\phi} + f(\phi) = 0$ where $f(\phi)$ is an odd polynomial is described. The technique consists of approximating $f(\phi)$ by an odd cubic, and hence obtaining an approximate solution in the form of a Jacobian elliptic function. The solution is compared to the classical Ritz solution of both one and two terms and is found to be superior. Also, the labor involved in obtaining the solution is considerably less, which makes the method easily applicable to various engineering problems involving the equation under consideration.

24,681 ABOUT SIGNAL FLOW GRAPH TECHNIQUES FOR SEQUENTIAL CIRCUITS by J. Brzozowski (U. Ottawa, Canada) and E. McCluskey (Princeton U.); IEEE Trans., Vol. EC-13, p. 154(L), Apr. 1964

Signal flow graph techniques are compared with Arden's procedure in regard to practicality, academic interest, and logic or experience.

24,682 SYNTHESIS OF UNITY-GAIN COMPLEX-ZERO RC NETWORKS by C.F. White (Naval Res. Lab.); Aug. 12, 1963, 14 pp., NRL 5972; U.S. Gov. Res. Rep., Vol. 39, p. 19(A), Mar. 5, 1964 AD 419 406 OTS $0.50

Resistance-capacitance networks provide filtering insertion loss variation with frequency. For prescribed voltage transfer functions containing complex zeros and negative-real poles, known synthesis procedures lead to RC networks exhibiting an undesirable frequency-independent loss. A new network synthesis procedure is set forth and applied to obtain: (a) four 7-element RC networks exhibiting damped complex zeros and (b) a 6-element RC network with undamped complex zeros of transmission. When these new networks are applicable, the prescribed transfer function is realized exactly, including the unity multiplicative constant. In addition, these networks have fewer elements than previous realizations.

24,683 REALIZATION OF TRANSFER FUNCTIONS OF RC: TUNNEL-DIODE NETWORKS by D.L. Losee (Cornell U.); Oct. 1963, 56 pp., Contract AF33 657 10682; U.S. Gov. Res. Rep., Vol. 39, pp. 44-45(A), Apr. 20, 1964 AD 429 117 OTS $6.60

Research showed that the use of tunnel diodes in RC network synthesis allows realization of arbitrary transmission zeros by means of grounded RC networks. The tunnel diode may be employed to either improve on the gain obtainable by passive realization techniques, or to obtain transfer functions which are neither RC-cascade nor RC-ladder realizable. A ladder network synthesis of positive real axis zeros is given realizing arbitrary gain. Then a cascade synthesis for right half-plane zeros is developed. Finally, it is shown that one tunnel diode, embedded in a network consisting of two paralleled RC ladders, is sufficient to realize any arbitrary transmission zeros. The diode requirements for this last realization are minimized. Lastly, brief consideration is given to the practical aspects of RC-tunnel diode synthesis.

24,684 SYNTHESIS OF THREE-TERMINAL $\pm$ R,C NETWORKS by C.L. Phillips and K.L. Su (Georgia Inst. Tech.); IEEE Trans., Vol. CT-11, pp. 80-82, Mar. 1964

A general method is developed which will synthesize a two-port network when all three short-circuit admittance functions y_{11}, y_{12} and y_{22}, that are realizable using positive resistors, capacitors, and negative resistors, are prescribed. The synthesized two-port is a three-terminal network. The method of synthesis involves the development of a separate component network for each type of pole that is realizable by a $\pm$R, C network. The short-circuit admittance functions are then realized by the parallel connection of the required component networks. An effort is made to keep the number of negative resistors as small as the method will permit.

24,685 SINGULAR NETWORK ELEMENTS by H.J. Carlin (Brooklyn Polytech.); IEEE Trans., Vol. CT-11, pp. 67-72, Mar. 1964

The properties of n-ports can be examined in terms of simple properties of linear vector spaces. This approach leads to a very general type of network formalism which in turn casts light on the physical realizability (or nonrealizability)

of the singular linear network elements: the nullator (simultaneously an open and a short circuit), and the norator (the unique nonreciprocal one-port with arbitrary port voltage and current). Furthermore, a two-port (the "nullor") which combines these two elements can be shown to be a unique active building block which exhibits the extraordinary nature of the two singular one-ports, but which has other properties which make it amenable for use in practical systems.

24,686 A NEW THEORY OF BROAD-BAND MATCHING by C.D. Youla (Brooklyn Polytech.); IEEE Trans., Vol. CT-11, pp. 30-50, Mar. 1964

The problem of designing an optimum, passive, reactive two-port equalizer to match out a dissipative frequency sensitive load to a resistive generator is solved. The method is simple and elementary and completely avoids any recourse to the Darlington equivalent of the load. Moreover, the technique is also applicable to the design of active equalizers.

24,687 INVESTIGATION OF RELIABILITY CHARACTERISTICS OF SOME COMPLEX NETWORKS by J.H. Stephenson (Air Force Inst. of Tech.); Aug. 1963, 49 pp., AFIT GRE EE63 4; U.S. Gov. Res. Rep., Vol. 39, p. 17(A), Mar. 5, 1964 AD 419 114 OTS $5.60

Reliability functions and a procedure are developed by which maximum reliable parallel-series and series-parallel networks may be designed. These networks are composed of equal elements having open and short circuit failure modes. Reliability functions are developed for bridge and lattice networks composed of unequal elements having a single failure mode. These functions are given in two forms, one suitable for substitution into more complex networks and one suitable for desk calculation and computer programming. Reliability functions are developed for two, three, four, and five station polygonal networks composed of equal paths with single failure modes. Reliability improvement is shown as stations are increased.

MICROCIRCUITS

24,688 MICROCIRCUIT DESIGN FOR THE CIRCUIT ENGINEER by E.A. Sack (Westinghouse); Electronic Design, Vol. 12, pp. 70-72, Jan. 20, 1964

The interrelationship of the individual integrated components for integrated nets is discussed, emphasizing economical and simple fabrication methods. The compatibility problem and component interconnection procedure is also presented, where the difficulty of completed product yield is recognized. Guidelines are offered to the circuit engineer who is faced with an overall system that is best divided into subnetworks. The selection of the the boundaries on these subnetworks is highly influential in the success of the silicon circuit.

24,689 TECHNOLOGY OF SOLID OR INTEGRATED CIRCUIT BLOCKS — A SURVEY by I.A. Lesk (Motorola Semicon.); Semiconductor Prod., Vol. 7, pp. 42-47, Mar. 1964

The technology of solid or integrated circuit blocks is derived from that used to make silicon transistors, but extended in all aspects when applied to the fabrication of silicon integrated circuits. This is especially true for compatible circuits, which incorporate thin film elements on the passivating oxide of a silicon substructure. Discussion is directed at the major features and problem areas of each of the technologies presently utilized to make monolithic integrated circuits.

24,690 INTEGRATED CIRCUITS DESIGN AND APPLICATION by R. Foglesong (Fairfield Semicon.); Semiconductor Prod., Vol. 7, pp. 32-42, Mar. 1964

The characteristics of components that can be used in integrated circuits are reviewed and general guidelines for designing integrated circuits are given. New constraints and new freedoms in integrated logic circuits are described. An example of how to specify integrated circuits is given, emphasizing the importance of testing the function of the circuit as a whole, rather than testing individual parts.

24,691 BASICS OF INTEGRATED CIRCUIT COMPONENTS by T.A. Ivesdal (Raytheon); Electronic Design, Vol. 12, pp. 50-55, Apr. 13, 1964

The necessity of electrical isolation in elements of an integrated circuit structure and its effect on the design and performance of the diode, transistor, resistor, and capacitor elements used in the circuit are discussed. The differences between the integrated transistor structure and that of the conventional discrete epitaxial transistor result in two parasitic elements characteristic of integrated circuit devices; an additional series resistance at the collector effectively increasing the saturation voltage, and a capacitance due to the substrate collector junction diode which, together with the resistance, forms a time constant lowering f_T. Reduction of the saturation voltage (to 100 mv range) and increase of f_T (to over 1 Gc) are obtained by use of a buried N+ layer. Five different arrangements of the basic integrated transistor structure to form diodes are discussed and the use of the basic structure to form capacitors and resistors is compared with thin-film methods.

24,692 INTEGRATED CIRCUITS — AN EVALUATION by I.A. Lesk (Motorola Systems Design, Vol. 8, pp. 30-32, Apr. 1964

The reliability of integrated circuits is evaluated. The three main sources of failure are bulk, surface, and metallic connection. High stress conditions for aging and testing are also discussed.

24,693 INTEGRATED CIRCUITS SHRINK A DOPPLER RADAR SYSTEM by E. Pacifico and S. King; Electronics, Vol. 37, pp. 74-79, Mar. 23, 1964

A procedure for designing analog circuits with integrated circuits is described. Several ways that analog portions of a doppler radar system were designed in microcircuit form are: application of thin-film, custom MIC (microelectronic integrated circuits), semi-custom MIC, and off-the-shelf hybrid approaches. The resulting equipment is smaller and lighter; more reliable, better performing, easier to maintain, and less expensive. The procedure is applicable to most radar systems.

24,694 THE DESIGN OF THIN-FILM CIRCUITS by C.D. Simmons (Philco); Semiconductor Prod., Vol. 7, pp. 21-27, Mar. 1964

The characteristics of presently feasible thin-film components and the special constraints imposed upon circuit design by the thin-film technology are discussed. A set of design rules is derived and a design procedure is discussed. This procedure is based on conventional design procedures as currently used with discrete components. Modifications are then made to adapt these conventional procedures to the special thin-film constraints. Some comments are made about specifications and steps to insure maximum efficiency in transferring design information from the ultimate user to the fabricator.

Thin Film Oscillators - See 24,747

24,695 A NOVEL HIGH-Q INDUCTANCE AND A TUNED OSCILLATOR FOR MICROMINIATURE CIRCUITS by S. Roy (U. Kalyani, India); Proc. IEEE, Vol. 52, pp. 214-215(L), Feb. 1964

The problem of producing a high Q inductance on a microcircuit by thin film techniques is solved by a simple inductive transistor circuit in which the maximum Q realizable is infinite with no instability at any frequency. The circuit consists of a compound connection of two transistors with an external resistance R_b at the base lead and a zero resistance in the collector lead. The circuit equations and input characteristics are derived, and some experimental results obtained with a compound connection of two OC71 transistors are given. In the present form, the device is found to be temperature sensitive.

24,696 THE FRUSTRATING PROBLEM OF INDUCTORS IN INTEGRATED CIRCUITS by W.E. Newll (Westinghouse); Electronics, Vol. 37, pp. 50-52, Mar. 13, 1964

Three different methods of tuning integrated circuits - active feedback, passive feedback, and feed forward nets - are presented and compared. Passive-feedback LC tuning networks are the ideal tuning method wherever they can be used. Selective active feedback networks are inherently very sensitive to component tolerances, and the required tolerances are not obtainable in the foreseeable future in integrated circuits. The feed-forward network is subject to self-oscillation and requires extreme tolerances. This objection can be overcome by using a finite number of stages but circuit complexity then becomes the limiting factor. No high-Q feed-forward network is known which promises to be economically feasible in integrated form.

24,697 SEMICONDUCTOR TECHNOLOGY AND MICROELECTRONICS by Ya. Fedotov; Jan. 30, 1964, 12 pp., Trans. from Radio (Moscow), pp. 28-31, Nov. 1963; STAR, Vol. 2, p. 552(A), Mar. 8, 1964 JPRS-22993; OTS-64-21437, $0.50

Miniaturization and increasing reliability of radio electronic apparatus, the roles of semiconductor technology in the solution of this problem, solid systems and molecular electronics are discussed.

CIRCUIT ASPECTS OF DEVICES

24,698 FERRORESONANT EFFECT CAUSED BY NONLINEAR CAPACITORS by A. Korpel and V. Ramaswamy (Zenith Radio); Proc. IEEE, Vol. 52, p. 82(L), Jan. 1964

The ferroresonant effect (jump phenomenon) in circuits using nonlinear capacitors lends itself to simple analysis in terms of large-signal theory. An evaluation is made of the magnitude of second harmonic capacitance variation C_2 in varactor diodes, based on measurements of the point of instability predicted by

e analysis. These results are shown to agree satisfactorily with experimental a obtained from large-signal parameter measurements as well as with theo- ical values derived by other authors. The ferroresonant effect thus emerges a convenient means for the experimental determination of C_2.

,699 OPERATION OF THE TUNNEL DIODE ABOVE RESISTIVE CUTOFF EQUENCY by G. Thomson (Airborne Instr. Lab., Cutler-Hammer); Proc. E, Vol. 52, p. 303(L), Mar. 1964

possible explanation for the apparent operation of a tunnel diode beyond the istive cutoff region as observed by Hoffins and Ishii [Proc. IRE, Vol. 50, pp. 98-1699, July 1962] is offered. It is suggested that in making the estimate 3.4 Gc for the resistive cutoff frequency, these authors failed to realize t according to the manufacturer's specification of the possible spread of the istance and capacitance values, cutoff frequencies as great as 20 Gc were fact possible. These would not be "typical" values of the parameters, but vertheless possible ones. Due to the extreme difficulty involved in measuring nel diode parameters in the X-band frequency region, it may be sometime ore this problem is resolved.

,700 OPERATING X-BAND TUNNEL DIODES AT Q-BAND by S. Jaslow- and K. Ishii (Marquette U.); Electronics, Vol. 36, pp. 32-33, Dec. 27,1963

method of achieving tunnel diode oscillations in the 33 to 50 Gc range, us- a diode rated for the 8 to 12 Gc range is discussed. A special tunnel diode veguide transformer and mount, designed so that the impedance of the micro- ve circuit matches the negative impedance at the tunnel diode at the desired quency, is used. This is accomplished by impedance transformation, with the nped junction and package capacitance of the packaged tunnel diode being nsformed into the distributed parameter capacitance of the waveguide, spe- lly designed film resistors had to be included in the mount to suppress low- quency parasitic oscillation. This technique is 12 times cheaper than using Q-band diode.

,701 BILATERAL SCR LETS DESIGNERS ECONOMIZE ON CIRCUITRY by K. Howell (GE); Electronic Design, Vol. 12, pp. 74-76, Jan. 20, 1964

description and circuit applications of the bilateral SCR are given. The de- ce is similar to the conventional SCR, having three terminals with agate for ggering, but operates on both polarities of the input waveform, thus acting fectively as 2 SCR's in full wave control system applications. First produc- on units can control 600w loads in 120 volt, 60 cycle circuits.

,702 BOOST FOR ELECTRONIC TUNING: Part I by L.A. Weldon and R. Kopski; Electronics, Vol. 37, pp. 49-53, Apr. 6, 1964

ning applications of voltage-variable capacitance diodes are discussed. Ma- r tuning changes may be made in milliseconds with only milliwatts of power pended. Two or more circuits may be tuned electronically to the same fre- ency, held in phase, and frequency power multiplied with good efficiency relatively high power levels. The diodes are smaller and more stable than chanical capacitors. Equivalent circuit diagrams and temperature plots are esented, and several applications in frequency tracking are described.

,703 MOLECULAR BLOCKS SIMPLIFY MICROCIRCUITS by V. Uzunoglu d M.H. White (Westinghouse); Electronics, Vol. 37, pp. 36-39, Feb. 14, 64

veral uses for double-base diodes and surface controlled devices are describ- l. Electrical characteristics of a double-base diode, tunnel diode, transistor th controlling oxide layer on its emitter-base junction, and diode with con- l grid are described. The surface controlled transistor can function as a ique memory device with: (1) gain, (2) output level proportional to input lse, (3) high input impedance, (4) information retained even with power fail- e, and (5) polarity discrimination. Two analog-digital conversion circuits e presented. One uses tunnel diodes and the other uses a surface controlled nsistor. The transistor is also described in the role of a transducer. Semicon- uctor temperature stabilization by means of a grid controlled diode and the rface layer transistor are also outlined.

4,704 TRANSISTOR OPERATING CONDITIONS. Part I by W. Tusting; Ind. lectronics, Vol. 2, pp. 132-134, Mar. 1964

he problems of biasing an earthed-emitter transistor and precautions for pre- nting the ratings of the transistor from being exceeded are discussed.

4,705 TEMPERATURE DEPENDENCE OF CIRCUITS USING TWO EMITTER OUPLED TRANSISTORS by L. Stanchi (Joint Nuc. Res. Ctr., Ispra, Italy); ct. 1963, 20 pp.; STAR, Vol. 2, p. 131(A), Jan. 23, 1964 EUR-370.e, vail. from Belgian Amer. Bank and Trust Co., N.Y., Acct. No. 121.86: 0 Bel. Fr.

he parameters of transistors which are influenced by temperature are examined. he analysis is made for difference amplifiers and Schmitt triggers and in gener- l for circuits which have two transistors with the emitters connected together. The theoretical investigation is followed by some results which were obtained on real transistors. As an example, the application to the Schmitt trigger circuit is given in order to demonstrate that, using simple design criteria and selection of components, it is possible to arrive at a remarkable stability without the use of a thermostat.

24,706 NOISE BEHAVIOR IN SEMICONDUCTOR DEVICES by E. Fonda (NASA); Electronic Ind., Vol. 23, pp. 72-78, Apr. 1964

Various types of noise phenomena in semiconductor devices are discussed and a technique to find minimum noise figure for transistor circuit design is presented. The transistor common base T equivalent circuit is analyzed with thermal, shot, and partition noise voltage and current sources. A definition of noise figure (NF) and its frequency dependence are given. NF for three transistor configurations is the same except for above a-cutoff, F_α, where the common collector and common base NF's continue to increase with frequency; the common collector NF theoretically becomes constant. Conditions for minimum NF are given and relations between transistor characteristics and NF are presented.

24,707 FIELD EFFECT TRANSISTORS [in German] by H.T. Röttgers; Elektron. Rund., Vol. 18, pp. 125-128, Mar. 1964

The three major types of field effect transistors are described and a short survey of new active semiconductor devices that are controlled without power consumption is presented. Applications are cited and the field effect transistor is compared to the bipolar transistor.

Circuit Applications of Field Effect Transistors - See 24,590

24,708 SOME ASPECTS OF THYRISTOR SERIES OPERATION by J.S. Lim and K. Wilson (Assoc. Semicon. Mfgrs. Ltd.); Mullard Tech. Commun., Vol. 7, pp. 266-270, Mar. 1964

Thyristors may be connected in series, so that the operating voltage of the circuit can be greater than the maximum voltage rating of a single device. Differences between the characteristics of individual thyristors can lead to unequal voltage sharing, and to possible destruction of devices by excessive voltages during the off state or in the interval between the turn-on of one thyristor and another. The principles of protection by means of parallel capacitors, parallel resistors, and series inductors are discussed; and the lines along which the design of practical protective circuits should proceed are indicated.

24,709 THE UNIJUNCTION TRANSISTOR IN RELAXATION CIRCUITS by B. Crawford and R.T. Dean (Texas Instr.); Electro-Technology, Vol. 73, pp. 34-38, Feb. 1964

Use of UJT's can bring about a sizable reduction in the parts required for multivibrators, comparators, pulse generators, and other circuits which depend on alternate triggering and relaxation of the active device. Stability criteria for such circuits are developed.

Circuit Applications of Unijunction Transistors - See 24,594

AMPLIFIERS

24,710 A TRANSISTOR AMPLIFIER WITH D.C. AND A.C. FEEDBACK STABILIZATION by H.C. Bertoya (Brit. Sci. Instr. Res. Ctr.); Electronic Engrg., Vol. 36, pp. 240-245, Apr. 1964

A transistor amplifier which uses a dc feedback loop in order to stabilize the dc working point is described. If the amount of ac feedback required does not coincide with the amount of dc feedback, it is possible to have two separate feedback loops. Direct coupling is used between stages which leads to a simple and economical design. Practical examples are given using both p-n-p and n-p-n transistors. One example was specifically designed for low noise application.

24,711 DIRECT CURRENT AMPLIFIER [in Spanish] by C. Marazzi (Com. Nac. Energia Atom., Buenos Aires); 1963, 11 pp., (Its Informe No.92); STAR, Vol. 2, p. 274(A), Feb. 8, 1964

A direct current amplifier whose gate is a solid-state chopper is described. This amplifier can be used in control circuits, and general applications are for measurement of temperature in thermocouples, or as an amplifier for a photosensitive element. The gate impedance is relatively low, serving principally as a current amplifier. It has been tried, whenever possible, to obtain a symmetrical characteristic of positive and negative values of the potential of the gate with respect to the exit.

24,712 DIRECT-COUPLED TRANSISTOR AMPLIFIER by M. Bronzite; Wireless World, Vol. 70, pp. 153-155, Mar. 1964

A dc amplifier circuit with gain of 12, gain variation 0.1 per cent, input range 0–±1 volt, input impedance 0–30 kΩ, output impedance as low as 1 kΩ, and drift referred to input of 300 μv/°C, is described. The amplifier is designed in three sections; high impedance pre-amp., main amplifier, and low impedance output. The pre-amp. uses bootstrapping to obtain high input impedance and includes a complementary emitter follower to provide thermal compensation for changes in V_{be}. The main amplifier consists of two complementary long-tailed pairs with feedback loops; one to increase common mode rejection, and the second to stabilize gain. The output stage is a class-B complementary type and uses a diode between the two transistor bases to reduce cross-over distortion and to provide bias compensation to prevent thermal runaway.

24,713 DESIGN OF HIGH-SPEED DIRECT-COUPLED AMPLIFIERS by D.J. Baker and C.L. Wyatt; Electronic Ind., Vol. 23, pp. 102–105, Mar. 1964

The design of a stabilized electrometer amplifier for use with photoemissive detectors is described. The need for a dc amplifier is best satisfied with the negative-feedback, direct-coupled, operation amplifier which has a frequency response extending to about 20 kc. A new method of stabilization using a neon glow tube is shown as well as design and analysis of an electrometer amplifier with a gain of 10^3 and a passband of dc to 20 kc. It also has a transfer function (sensitivity) of 10^{14} volts/ampere.

24,714 TECHNIQUES FOR THE EVALUATION AND UTILIZATION OF TRANSISTORS IN THE UHF REGION by L.L. Lehner and D.W. Taylor; IEEE Trans., Vol. BTR-10, pp. 9–13, May 1964

In the UHF frequency range where a quarter wavelength is of the order of 10 cm, it is usually quite difficult to perform accurate measurements, especially in the case of transistor amplifiers. Some techniques that can be used to obtain performance data and to construct practical amplifiers for gain and noise figure measurements are described. As is the case with most circuit techniques, an impedance bridge is essential.

24,715 SOLID STATE MICROWAVE AMPLIFIERS by E.T. Hooper, Jr. (Naval Ord. Lab.); in ONR Solution to Navy Probl. through Adv. Tech., 1963, pp. 189–205; STAR, Vol. 2, p. 811(A), Apr. 8, 1964 ONR-16, Vol. 1, OTS $5.00

Amplifiers are classified according to their local power and the agent employed. In the first group described, the agent is free, i.e., it has translational energy of motion and, as a consequence, is excited by direct local power. In the second group, the agent is bound or constrained and is excited by alternating local power. Amplifiers using alternating local power are discussed in detail. Of this type, the solid-state parametric diode and parametric magnetic amplifiers are the principal contenders for a solution of the microwave amplifier problem. The operating principles of solid-state parametric amplifiers are discussed. The general theory of parametric pumping is applied to the case of the ferromagnetic microwave amplifier in an effort to reduce the noise.

24,716 CRYOGENICALLY COOLED X-BAND PARAMETRIC AMPLIFIER by J. Sadler and W. Wells, Jr. (Texas Instr.); Proc. IEEE, Vol. 52, p. 305(L), Mar. 1964

The design of an X-band nondegenerate parametric amplifier operated at 77°K is described. This amplifier has exceptionally low noise figures at both cryogenic and room temperatures. The amplifier is pump-tuned to allow tuning while immersed in liquid nitrogen. The amplifier signal circuit is composed of a waveguide-to-coaxial transition, a coaxial transformer and a low-pass coaxial filter terminating in a GaAs pill-packaged varactor diode. It has more than a 40-Mc bandwidth (3 db points) across the tuning range at 15-db gain and is pumped in the 24 Gc region. The noise figure of this amplifier when tuned across the band from 7.9 to 8.7 Gc was always less than 3 db at room temperature and always less than 0.8 db when cooled by liquid nitrogen.

24,717 A LOW-NOISE K_u-BAND NON-DEGENERATE PARAMETRIC AMPLIFIER by J. Whelehan and E. Moley (Cutler Hammer); Proc. IEEE, Vol. 52, pp. 209–210(L), Feb. 1964

A low noise K_u-band parametric amplifier for operation at 16 Gc is described. The amplifier exhibits a gain of 20 db with a bandwidth of 40 Mc for a center frequency tunable over 100 Mc by varying bias alone and tunes 1 Gc by changing the pump frequency or mechanically tuning the amplifier. A broadband four-port circulator interconnects the amplifier with the antenna and the receiver to provide a large gain-bandwidth product with good operational stability and low noise factor (3.2 db). A graded silicon junction is the active element which is pumped at 39.5 Gc.

24,718 PUMPING CONDITIONS FOR PARAMETRIC GAIN WITH A NONLINEAR IMMITTANCE ELEMENT by R.A. Pucel (Raytheon); Proc. IEEE, Vol. 52, pp. 269–276, Mar. 1964

The necessary conditions for parametric amplification obtained by Penfield for the series nonlinear capacitive-linear resistive element are extended to the case when the resistive element is also nonlinear. The role played by the pho angle between the capacitive and resistive modulation is also taken into account. On the basis of the gain criteria, a figure of merit of a parametric el ment applicable to the pumped condition is also extended to include the type of element considered. The most favorable pumping phase is demonstrated to that for which the capacitive variation at the pump frequency lags the resisti variation by 90° in phase. None of the nonlinear elements now being used f parametric applications satisfies the favorable phase condition. A convenient gain-frequency graph summarizing most of the theoretical conclusions is presented. It is also proved that for the case where the signal frequency is lower than the idler frequency, the highest frequency of operation obtainable with an existing series capacitive-resistive element can never be increased by the addition of a passive series nonlinear resistor, regardless of the pumping phas achievable by this addition.

24,719 NON-RECIPROCAL PARAMETRIC AMPLIFIERS: THEORY AND INSTRUMENTATION by H.B. Henning (LFE Electronics); IEEE Trans., Vol. BTR 10, pp. 55–64, May 1964

The advantages of a non-reciprocal parametric amplifier over conventional types are manifest. Perturbations in signal source characteristics no longer de grade stability and power gain. For this reason, conventional paramps require circulators. But circulators are noisy, temperature sensitive, and complicate any attempts to cool the paramp cryogenically. To overcome these difficulties the theory of non-reciprocity is applied to two single-varactor paramps. One paramp operates in a CW mode, the other is superregenerative. Both units w (a) provide down-conversion and (b) accommodate signal frequencies which e ceed the nominal value of the pump. Design constraints and performance cha acteristics are discussed.

24,720 A BROAD-BANDING THEORY FOR VARACTOR PARAMETRIC AMPLIFIERS. Part I by W.H. Ku (Sylvania); IEEE Trans., Vol. CT-11, pp. 50–58, Mar. 1964

A general and rigorous broad-banding theory for varactor parametric amplifie is developed. The parametric device exhibits some inherent network properti which are not shared with other two-terminal active devices. When the varac tor is embedded in an arbitrary passive environment, it presents an impedanc that can be characterized by a positive function rather than a positive-real function. The broad-banding theory presented also takes into account the int action between the signal and sideband circuits through the frequency couplin action of the variable capacitor. Realizability conditions on the transducer power-gain function of a varactor parametric amplifier are derived. It is sho that the prescribed transducer power-gain function must satisfy a set of restric tions derived in part from the parasitic elements of the varactor. The main results of this paper are embodied in two theorems which describe a synthesis me od for the realization of broad-banding parametric amplifiers using varactors. It is shown that the synthesis requires, in general, two factorizations of the p scribed transducer power-gain function.

24,721 A BROAD-BANDING THEORY FOR VARACTOR PARAMETRIC AMPLIFIERS. Part II by W.H. Ku (Sylvania); IEEE Trans., Vol. CT-11, pp. 59–66, Mar. 1964

Fundamental gain-bandwidth limitations are derived for parametric amplifiers using varactors. These limitations are fundamental in that they are independe of the associated circuitry. For a single varactor parametric amplifier with id flat response, the optimum gain-bandwidth limitation is derived as

$$G_{T\max} = \cosh^2\left[\frac{\pi\sqrt{\omega_{s0}\omega_{i0}}C_1}{\omega_c C_0}\right],$$

where $G_{T,max}$ is the maximum flat transducer power gain, ω_c is the equivale power-pass bandwidth, ω_{s0} and ω_{i0} are the respective signal and idler band-center frequencies, and C_0 and C_1 denote the first two coefficients of a linea variable capacitor. Explicit formulas are presented for the design of modified Butterworth and Chebyshev characteristics of arbitrary orders and it is shown that both approach the ideal flat response over the prescribed band as the ord is increased. When the series parasitic inductance L of the varactor is consid ered, there is an additional limitation given by

$$G_{T\max} = \cosh^2\left[\frac{\pi\sqrt{\omega_{s0}\omega_{i0}}C_1(3C_0 - \omega_{s0}\omega_{i0}C_1^2L)}{\omega_c^3LC_0^3}\right].$$

24,722 INVESTIGATION OF THE STABILIZATION OF PARAMETRIC AMPLIFIERS by D.E. Allen and R.B. Butterton (Motorola); Dec. 5, 1963, 57 pp., Contract AF19 628 433; U.S. Gov. Res. Rep., Vol. 39, p. 45(A), Apr. 20, 19 AD 429 159 OTS $6.60

New techniques for the stabilization of the gain of parametric amplifiers used in the front end of radiometer receivers have been investigated. A summary o the basic theory of parametric amplifiers is given with emphasis on the degen-

ate mode of operation as applied to receiver front ends for microwave radiometry. The development of a 15.5 Gc amplifier is described. This amplifier utilizes gain stability by feedback of a reference noise level to control the pump power. The amplifier has 17 db gain, 70 Mc bandwidth, and 3.0 db noise figure. The utilization of feedback results in a 15 to 1 improvement of gain stability for pump power changes. A 1.0 Gc degenerate mode amplifier for use as the first stage of a radiometer IF amplifier is developed. A feasibility study of a degenerate mode K_a-band parametric amplifier is described.

24,723 NOISE PERFORMANCE OF PHOTODIODES IN PARAMETRIC AMPLIFIERS by K. Garbrecht and W. Heinlein (Siemens and Halske); Proc. IEEE, Vol. 52, pp. 192-193(L), Feb. 1964

The noise performances of a pumped varactor diode amplifier simultaneously used as a photodiode in an optical receiver of microwave modulated light and a cascade consisting of a photodiode followed by a separate preamp are compared. The signal-to-noise ratios (SNR) of both systems are derived from their noise equivalent circuits. The simultaneous use of the photodiode as a parametric amplifier diode degrades the SNR of the receiver. The physical cause is that in a combination photo preamp, the photodiode in the signal circuit must be heavily mismatched and shot noise of photocurrent at idler frequency is additionally transformed into the signal circuit.

24,724 PARAMETRIC AMPLIFIER by B.J. Zajac and H. Schenker; U.S. Pat. 3,125,687, Issued Mar. 17, 1964

A parametric amplifier having a voltage gain characteristic substantially greater than one and relatively low power requirements is proposed. Transformer means having optimum performance characteristics at the pump frequency are incorporated to obtain voltage amplification prior to demodulation of the signal in the output stage.

24,725 PARAMETRIC AMPLIFIER FOR THE RANGE 220 TO 250 Mc [in German] by A. Ott; Elektron. Rund., Vol. 18, pp. 83-85, Feb. 1964

The mode of operation, design, and measurements for a 220-250 Mc capacitive diode parametric amplifier are discussed. The amplifier is comprised of a single unit containing the amplifier circuit, pump-frequency generator and a dc voltage supply.

24,726 GAIN CONTROLLED BAND-PASS AMPLIFIERS. A NEW APPROACH USING INTEGRATED CIRCUIT VIDEO AMPLIFIERS by M.D. Wood (Wood-Ferranti); Electronic Engrg., Vol. 36, pp. 150-153, Mar. 1964

The difficulties of gain controlling HF tuned transistor amplifiers are reviewed. The particular problems associated with high Q circuits and neutralization are discussed in this context, along with the conventional methods used to overcome them. Various methods of gain control are then outlined and discussed, with specific reference to their effect on the tuning of the amplifier. A few general points about gain control are considered which may impose their own limitations on the amplifier design. In the second part the idea of using a video amplifier with tuned input and output stages to define the band shape is introduced and developed. It is shown that the integrated circuit video amplifier which is described, not only overcomes these difficulties, but has additional advantages to offer.

24,727 USING INTEGRATEDS AS FEEDBACK AMPLIFIERS by L. Housey and G. McFarland (Texas Instr.); Electronic Design, Vol. 12, pp. 49-52, Mar. 2, 1964

Specific examples of inverting, non-inverting, and differential amplifiers using Texas Instrument's Series 52 operational amplifiers are discussed. Closed-loop gain calculations as well as methods for determining feedback configuration are presented.

24,728 DIODES REPLACE STEP-UP TRANSFORMER by D.R. Mathews (Lear Siegler); Electronic Design, Vol. 12, pp. 71-72, Apr. 13, 1964

A transistor amplifier using blocking diodes to allow a pulse amplitude output greater than the dc bias voltages used in the circuit is described. The maximum output voltage is limited only by the PIV of the diodes, the maximum V_{ce} of the transistors, and the voltage ratings on the capacitors.

Pulse Amplifiers - See 24,757 and 24,765

24,729 A NEW LOW-LEVEL FAST RECOVERY PRECISION NULLING AMPLIFIER; Data Sys. Engrg., Vol. 18, pp. 38-41, Dec. 1963

A new analog instrument used as a plug-in preamplifier for oscilloscopes is described. Observation of small deviations in a large signal, accurate low level measurements immediately following a large signal and measurement of a small selected "slice" (in time or amplitude) of a large signal are possible. Input resistance is variable from 0 to 1 megohm. The maximum input voltage is from 15 volts to 500 volts, depending on the sensitivity setting which ranges from 10^{-1} volts/cm to 10^{-4} volts/cm. The preamplifier is adaptable to any oscilloscope accepting Tektronix letter-series plug-ins.

24,730 RATING PRE-AMPS BY "MINIMUM DETECTABLE SIGNALS" by K. Ishii; Electronic Ind., Vol. 23, pp. 100-101, Mar. 1964

A method of measuring the minimum detectable signal (MDS) of a microwave preamplifier, or a millimeter wave preamplifier using an auxiliary receiver, is proposed. This method separates the MDS of the preamplifier from the influence of the rest of the system, giving the MDS free of the auxiliary receiver's noise or gain. The MDS is a more important factor than the noise figure for evaluation of preamplifiers.

FM Preamplifiers - See 24,778

24,731 PRELIMINARY ANALYSIS OF THE TRANSISTOR TUNED POWER AMPLIFIER by J. Furlan (U. Ljubljana, Yugoslavia); Proc. IEEE, Vol. 52, p. 311 (L), Mar. 1964

An approach to the analysis of the transistor tuned power amplifier using linearized transistor characteristics is described. This method provides an explicit solution for the optimum performance of the transistor tuned power amplifier with regard to output power and collector efficiency of transistors. A three dimensional graphical analysis of the grounded emitter configuration is made representing the characteristics of the transistor linearized by a plane in space, determined by the coordinates I_C, V_{CE}, V_{BE} or I_C, V_{CE}, I_B. Expressions that give parameters to optimize output power and collector efficiency are derived from the graphical model.

24,732 HIGH DYNAMIC INPUT IMPEDANCE AMPLIFIER by J.L. Diclue (Minn.-Honeywell); U.S. Pat. 3,125,693, Issued Mar. 17, 1964

A high dynamic input impedance photodiode amplifier circuit is described. The circuit is comprised of a small number of semiconductor elements arranged in two emitter follower stages, a common emitter and a constant current stage. Both stages have a transistor connected with an emitter follower output and serve as preamps for the impedance match.

24,733 MICROWAVE TUNNEL-DIODE AMPLIFIERS WITH LARGE DYNAMIC RANGE by R. Steinhoff and F. Sterzer (RCA); RCA Rev., Vol. 25, pp. 54-66, Mar. 1964

The large-signal behavior of tunnel-diode amplifiers is analyzed, and curves for calculating the gain-saturation characteristics of gallium arsenide, germanium, and gallium antimonide tunnel-diode amplifiers are presented. Agreement between theory and experiment is good. The design of microwave tunnel-diode amplifiers with dynamic ranges of about 90 decibels (for 1 Mc noise bandwidth) is then discussed, and experimental results obtained with such amplifiers are given.

OSCILLATORS

24,734 HIGH Q, BT-TYPE, QUARTZ OSCILLATOR by A. Seed (Stand. Tel. and Cables); J. Sci. Instr., Vol. 41, p. 242(L), Apr. 1964

The design of a BT-type quartz oscillator, operating on the third overtone and having a Q value of 2×10^6 at a frequency of 15 Mc, is described. For a crystal element cut to the specification of (yxl)—46°, the zero temperature coefficient of frequency occurred at 24.8°C.

24,735 A DESIGN APPROACH TO TRANSISTORIZED VOLTAGE-CONTROLLED CRYSTAL OSCILLATORS by P. Boyle (GE); Electronic Design, Vol. 12, pp. 22-26, Mar. 2, 1964

The design of transistorized voltage-controlled crystal oscillators for use as servo elements in phase-locked loops is discussed. The procedure outlined permits the design of oscillators in the 1-Mc to 10-Mc range with stabilities of one part in 10^8. The basic oscillator loop consists of a collector-to-emitter series feedback loop. Frequency control is obtained with voltage-variable capacitors.

24,736 ELEMENTS OF TRANSISTOR PULSE CIRCUITS, TRANSISTOR ASTABLE MULTIVIBRATORS by T.D. Towers (Newmarket Transistors Ltd.); Wireless World, Vol. 70, pp. 128-132, Mar. 1964

The operation and applications of multivibrator circuits, particularly the astable transistor multivibrator, are discussed. The circuit operating principles and variations of circuit parameters to produce high and low frequency limits are explained. Applications of the astable multivibrator as a square wave generator and as a frequency divider using either a sine wave or square wave as the synch signal are also discussed.

24,737 NOVEL MULTIVIBRATORS TEST TAPE TRANSPORTS by C.J. Dakin; Electronics, Vol. 37, pp. 40-43, Feb. 14, 1964

Design data for three multivibrator circuits in which frequency and mark to space ratio can be independently varied are presented. One design uses two transistors with two Shockley diodes for a change-over switch, another uses four transistors and a third more complex circuit has six transistors and two OA 47's. Disadvantages of supply voltage-frequency dependence and inferior output waveform of the Shockley design are overcome in the transistor circuits. The more complex transistor design allows frequency changes of 15:1 and the mark to space ratio is changed from 1:15 to 15:1.

24,738 A NEW TYPE OF FREE-RUNNING MULTIVIBRATOR by V.M. Ristic (U. Belgrade); Electronic Engrg., Vol. 36, pp. 232-233, Apr. 1964

A series type emitter coupled multivibrator using two p-n-p transistors is described. The circuit has good rise and fall times and will oscillate between 0.01 cps and 250 kc.

24,739 FOUR-LAYER DIODE MAKES SIMPLE ASTABLE MULTIVIBRATOR by J. Chesebro (Collins Radio); Electronic Design, Vol. 11, p. 56, Dec. 20, 1963

An astable multivibrator which uses a four-layer diode with an RC charging network is described. It has a wide range of pulse repetition rates and any desired degree of dissymmetry. Its advantages are small size, use of relatively few components, low power dissipation, ability to work with a wide range of voltages, and speed of operation. An illustration as well as design equations are provided.

24,740 SPEEDING THE DESIGN OF UNIJUNCTION-TRANSISTOR MULTIVIBRATORS by T.P. Sylvan and R.L. Wilson (GE); Electronic Design, Vol. 12, pp. 28-32, Mar. 30, 1964

The operation, design, synchronization, and coupling of a "standard" astable multivibrator using a unijunction transistor are discussed. The frequency and duty cycle of the circuit are adjustable by varying circuit parameters; a nomogram for quick graphical solution of the equations governing these parameters is presented. Synchronizing is possible using pulses, a sine wave, or other waveforms and coupling for low signal amplitude output by means of a transformer and for high amplitude output by means of the gate-to-cathode diode of a gate-turn-off silicon controlled rectifier.

24,741 ELEMENTS OF TRANSISTOR PULSE CIRCUITS, TRANSISTOR MONOSTABLE MULTIVIBRATORS by T.D. Towers (Newmarket Transistors Ltd.); Wireless World, Vol. 70, pp. 199-203, Apr. 1964

The operation of both collector- and emitter-coupled monostable multivibrators is explained, and the changes in transistors and other circuit elements necessary to produce low, medium, and high-speed circuits are described. Complimentary symmetry multivibrators, (using both p-n-p and n-p-n transistors in combination), are also discussed. Applications mentioned include generation of precise pulses, reshaping pulse trains which have degenerated during transmission, stretching narrow pulses into wider ones, generation of time delays, gating control circuits, and frequency division.

24,742 PHASING IN ON TRANSISTORIZED PHASE-SHIFT OSCILLATORS by J.J. Nagle (Westinghouse); Electronic Design, Vol. 12, pp. 32-37, Apr. 13, 1964

The operation and design of both resistive and capacitive shunt transistorized RC phase shift oscillators are discussed. Four curves are presented showing the frequency factor and attenuation of the phase networks (resistive and capacitive shunt). Use of the curves to design and analyze the frequency stability with respect to the load resistance of a 1000 cycle phase shift oscillator is demonstrated.

24,743 TRANSISTOR WIEN BRIDGE OSCILLATORS FOR 20 C/S TO 300 KC/S; Electronic Applic., Vol. 23, No. 4, pp. 164-168, 1962-1963

A practical Wien bridge oscillator is described. The stabilized output is approximately 1.0v, and total distortion at 1.0 kc/s is less than 0.5 per cent. Alternative component values are given for operation at fourteen different frequencies in the range of 20 c/s to 300 kc/s. The measured frequencies are within ±3 per cent of the theoretical values.

24,744 TRANSISTORIZED WIEN BRIDGE OSCILLATORS AND FEEDBACK AMPLIFIERS by R.H. Okada; Solid State Design, Vol. 5, pp. 29-32, Mar. 1964

The Wien Bridge Oscillator circuit is well known and frequently utilized in electronic circuitry. However, many of the textbook explanations and papers on the subject are vague and sometimes erroneous. The analysis of the circuit is clarified and the functional dependence of the various circuit parameters is derived. Design equations are given for the associated amplifier, and a practical circuit is shown for illustrative purposes.

24,745 CONDITIONS OF OSCILLATION FOR WAVEGUIDE MOUNTED TUNNEL DIODES by C.C. Hoffins and K. Ishii; IEEE Trans., Vol. MTT-12, pp. 176-183, Mar. 1964

Double frequency oscillation due to the frequency dependency of the waveguide's distributed parameters was observed in a waveguide mounted tunnel diode circuit. A general analysis of the frequency dependent diode load is made and conditions of oscillation are formulated. The analysis is extended to a 1N3219A diode mounted in a tapered RG-52/U waveguide used as an oscillator. The load impedance to the tunnel diode is derived with the diode mounted at the center of the waveguide. A numerical example involving the waveguide mount verifies the existence of double frequency oscillation. Off center diode mounting is examined. It is concluded that the waveguide mount's distributed parameters are highly frequency dependent at the center of the guide and thus double frequency oscillation can exist when a tunnel diode is mounted at that point. With the diode mounted at any other point, only one oscillation frequency can be observed. The frequencies of oscillation of a waveguide mounted tunnel diode oscillator are determined only by the real roots of the resistive component of the total tunnel diode load impedance.

24,746 FREQUENCY SHIFT OF A TUNNEL-DIODE MICROWAVE OSCILLATOR by T. Arizumi and T. Wada (Nagoya U.); Japanese J. Appl. Phys., Vol. 3, pp. 150-154, Mar. 1964

The oscillation frequency in a tunnel-diode microwave oscillator varies depending upon both the ambient temperature and the bias voltage. This variation can be interpreted mainly by the change in the junction capacitance. At medium bias voltages the temperature dependence of the junction capacitance is in agreement with those estimated from Bernard's results at low frequencies. At higher bias voltages the variation in the frequency as a function of bias voltage are primarily caused by the nonlinear I-V characteristic, while at lower bias voltages the anomaly of the junction capacitance as well as the nonlinearity determines the variation in the oscillation frequency.

24,747 FABRICATE YOUR OWN THIN-FILM OSCILLATOR by L.W. Sumney and C.E. Holland (U.S. Naval Res. Lab.); Electronic Design, Vol. 12, pp. 52-56, Mar. 30, 1964

A complete run-down on the techniques and materials required for fabrication of circuits in thin film form is presented. A design for an 8 Mc crystal oscillator is translated into thin film form and fabricated by an illustrated step-by-step procedure. A complete list of the equipment (chiefly a vacuum chamber), and materials necessary for the project are also included.

24,748 THE ELECTRON SPIN OSCILLATOR by E.L. Sloan III, A. Ganssen and E.C. LaVier (National); Appl. Phys. Lett., Vol. 4, pp. 109-110(L), Mar. 15, 1964

The continuous operation of an electron spin oscillator at X-band (~9.6 Gc/sec) frequencies is discussed. A pair of orthogonal coils, a transmitter coil that excites the spin precession and a receiver coil that picks up the spin precession with a diphenyl picryl hydrazyl (DPPH) sample common to both, is used. The spin induction signal is amplified and (with correct phase shift) applied to the transmitter coil. The system was carefully designed so that the two orthogonal cavity modes were decoupled by better than 60 db even when resonant at the same frequency. Oscillation was achieved with a nominal 20 db amplifier gain. The oscillation frequency is controlled by the electron paramagnetic resonance and thus by the magnitude of the bias magnet field. Improved operation is expected with a non-resonant structure and stable traveling wave tube assemblies. A stability of 10^{-11} for DPPH is predicted.

SWITCHING CIRCUITS

24,749 ON A METHOD OF SIMPLIFICATION OF MULTIPLE-OUTPUT SWITCHING FUNCTIONS by A.K. Choudhury, M.S. Basu and S.R. Das (Calcutta U.); J. Electronics and Control, Vol. 16, pp. 223-237, Feb. 1964

A method for finding out the simplest two-stage expression for a given multiple-output switching function requiring minimum number of AND-blocks is presented. The different component functions of the given multiple-output function are plotted on a chart. A knowledge of the weights of the minterms, prime implicants and the essential prime implicants of the individual component functions enables one to determine easily from the chart the multiple-output prime implicants (or Mopi's) which are essential. In the next step, those Mopi's are selected which satisfy the condition for being included in one of the minimal covers. Finally, other Mopi's are selected by trial for the coverage of the still uncovered terms. A procedure has also been suggested for finding out a cover requiring minimum number of diodes for two-level circuit realization of the given multiple-output function starting from a minimal Mopi cover. The method can be suitably modified for simplification of functions incorporating a certain number of 'don't care' states.

24,750 SWITCHING TIME OF A GROUNDED EMITTER TRANSISTOR CIRCUIT by T. Koshiba and K. Tomaru (NTT); Rev. Electr. Commun. Lab., Vol. 12,

), 233-243, Mar.-Apr. 1964

ie switching time of a grounded emitter transistor with an RC parallel input rcuit was analyzed by means of charge control parameters. The effects of a eed-up capacitor, a reverse drive voltage, and a reverse bias voltage were ken into account. The calculated values were compared with measured val-s, and good agreement was confirmed.

4,751 A MORE ACCURATE METHOD OF DESIGNING TRANSISTORIZED CHMITT TRIGGERS - Part I by R.A. Jensen (IBM); Electronic Design, Vol. , pp. 40-45, Mar. 30, 1964

modified version of the basic Schmitt trigger circuit is given including a ep-by-step design procedure, examples, and experimental verification. The ddition of a resistor between the emitter and the supply in a typical dc-cou-ed Schmitt trigger validates the assumption that the switching (triggering) and turation levels of the transistors are the same. From this modification and re-lting assumptions, there follows a seven step procedure for determining circuit rameter values.

4,752 J-K FLIP-FLOP REDUCED CIRCUIT COMPLEXITY by D.C. Davies d W.O. Hanlin (Fairchild Camera and Instr.); Electronic Design, Vol. 12, . 62-64, Mar. 30, 1964

J-K flip-flop circuit well suited to integration (since it employs no capaci-rs) and usable in a counter without additional circuit is described. Conven-onal flip-flops have unpredictable outputs when both inputs have the same gic level; added logic circuitry is usually necessary to prevent the undesired put condition. An advantage of the J-K flip-flop over a capacitor coupled rcuit is that it will function properly with a variety of clock pulse wave-apes.

4,753 MULTIVIBRATOR SWITCHES WITH SUPPLY VOLTAGE CHANGE by .R. Hayes (Royal Coll. of Adv. Tech., Salford, England); Electronic Design, ol. 12, pp. 74-75, Apr. 13, 1964

bistable multivibrator that switches with change in supply voltage by means a Zener diode located in one coupling arm of the circuit is described. This pe of circuit could be used in special trigger circuits, warning and protec-on devices, and simulation of electromechanical relays.

4,754 MAGNETIC SWITCHING DEVICE by G. Constantine, Jr. (IBM); .S. Pat. 3,126,533, Issued Mar. 24, 1964

load-sharing magnetic switch designed for low noise output is described. our sets of two read windings are wound over eight toroidal cores in an ap-ropriate pattern. Each core has an output winding and an additional write inding. When four windings are excited (one from each pair), one core will ave its magnetic state changed. A "complementary" core also receives an im-ulse, but the polarity of the pulse is such that the magnetomotive force is in e same sense as the core's position on its hysteresis curve. The windings are rranged so that the net magnetic impulse delivered to the other six cores is ero. The only spurious output comes from the "complementary" core because does not have a perfectly square hysteresis curve. After switching, the write inding returns the core to its original state, producing an output pulse of op-osite polarity together with small spurious pulses on the other core windings ue to the imperfect hysteresis curve.

SIGNAL CONVERTERS

4,755 OR CIRCUIT AMPLITUDE MODULATOR by J. Furlan (U. Ljubjana, ugoslavia); Proc. IEEE, Vol. 52, pp. 311-312(L), Mar. 1964

A simple circuit for an amplitude modulator which transforms carrier and mod-ulating signals directly to the amplitude modulated wave is described. Four iodes and two signal input transformers are the components used. The circuit s analyzed theoretically. In order to avoid higher harmonics of the carrier requency due to distortions, it is convenient to load the modulator output with parallel resonant tuned circuit tuned to the carrier frequency.

24,756 A WIDE-RANGE AUDIO-FREQUENCY PULSE MODULATOR by M.E. Bryan (Royal Coll. Adv. Tech., Salford) and W. Tempest (U. Liverpool); Electronic Engrg., Vol. 36, pp. 154-158, Mar. 1964

A two-channel audio frequency pulse modulator is described. Each channel will modulate an audio frequency signal to provide a pulse of 0.5 msec to 5 sec length in either of two envelope shapes; the rise and fall times of the pulse are independently variable in the range of 0.3 msec to 100 msec. The level of hum noise, and harmonic distortion in the pulse and in the period between pulses is more than 50 db below the pulse level. The two channels can be used to provide an A-B-A-B- ..... sequence of pulses in which the characteristics of pulses A and B are independently variable.

24,757 A PULSE MODULATOR THAT CAN BE USED AN AN AMPLIFIER, A MULTIPLIER, OR A DIVIDER by J.A. Rosenthal; IEEE Trans., Vol. IM-12, pp. 125-134, Dec. 1963

A pulse modulator that can be used as an amplifier, a multiplier, or a divider is introduced. Some of its desirable features are that it can respond without delay to a change in input signal, it is of very simple construction and it can be used to control either proportional or on-off systems.

24,758 LOW NOISE TUNNEL DIODE MIXERS AND CONVERTERS by S. Becker, G. Hiller and R. Pettai (Micro State Electronics); Final Rept. Dec. 17, 1963, 70 pp., Contract AF30 602 2631; U.S. Gov. Res. Rep., Vol. 39, p. 46(A), Apr. 20, 1964 AD 429 176 OTS $7.60

Experimental and theoretical results of a program to develop and construct low-noise tunnel diode mixers and converters are reported. Studies lead to a conclusion that reasonably low noise figures are possible when the diode is biased near the valley. This allows the tunnel diode converter to be operated with positive input and output conductances which simplifies the stability problem. The possibility of conversion gain with positive terminal conductances is also discussed. Assumptions which limit the accuracy of the theoretical results are pointed out. A separate section is devoted to the theory of measurement techniques and apparatus.

24,759 TUNNEL DIODES AS MILLIMETER WAVE DETECTORS AND MIXERS by P.E. Chase and K.K.N. Chang; IEEE Trans., Vol. MTT-11, pp. 560-561, Nov. 1963

A tunnel diode used as a 55 Gc detector and mixer is described. Alloying techniques were used to fabricate the tunnel diodes which were then integrated into a tapered section of RG-98/U waveguide. An improvement of about 10 db in the system noise figure was observed when the tunnel diode was used as the mixer compared to the same system with a 1N53 crystal as the mixer. A tangential sensitivity of -82 dbm was observed with the tunnel diode as compared to a tangential sensitivity of -71 dbm for a 1N53 crystal.

Laser Pulse Detectors - See 24,640

24,760 FREQUENCY MULTIPLICATION BY MEANS OF VARACTOR DIODES. Part I. THE FREQUENCY DOUBLER [in German] by A. Kach (Brown, Boveri and Co., Baden (Schweiz); Arch. Elektr. Uebertragung., Vol. 18, pp. 161-173, Mar. 1964

The transfer properties of the frequency multiplier with varactor diode, in particular those of the frequency doubler, are discussed in terms of large-signal theory and general relations are devised concerning conversion loss, relative power values, matching conditions, and bandwidth. The maximum attainable efficiency depends merely on the ratio of the respective operating frequency to the limit frequency of the varactor diode. To attain high doubling efficiency (e.g. 80 per cent), the diode limit frequency must be about a hundred times above the fundamental frequency to be doubled. The maximum possible relative bandwidth of the frequency doubler is found to be about 25 per cent.

24,761 MICROWAVE GENERATION THROUGH FREQUENCY MULTIPLICATION USING LOW-LOSS VARACTOR DIODES [in German] by A. Kach (Tech. Hoch., Zurich); Scientia Electrica, Vol. 10, pp. 1-23, 1964

Modern low-loss reactance diodes allow the design of frequency multipliers of considerable efficiency. The properties of reactance diodes and the essential design considerations for such multipliers are described. The conversion loss is established on the basis of an extended small signal theory. Experimental multipliers are described, and their performance is discussed on the basis of measured results.

24,762 UNILATERAL PARAMETRIC FREQUENCY CONVERTERS WITH NONLINEAR CONDUCTANCE AND CAPACITANCE by M. Beddoes and W. Little (U. Brit. Columbia); Proc. IEEE, Vol. 52, p. 332(L), Mar. 1964

A method of obtaining unidirectional signal flow in parametric frequency converters through in-phase pumping and proper termination of an image circuit is described. The pumped nonlinear conductance and capacitance are expressed by Fourier series in the analysis of the small signal model of the parametric frequency converter. Expressions giving the relationships between the capacitance and conductance Fourier coefficients necessary for operation as a unilateral up-converter or down-converter are derived.

Frequency Dividers - See 24,736

PULSE CIRCUITS

24,763 PULSE GENERATOR SYSTEM FOR FAST-REACTION EXPERIMENTS USING A TIME-OF-FLIGHT MASS SPECTROMETER by J.S. Riney and W.C. Gardiner, Jr. (U. Texas); Rev. Sci. Instr., Vol. 35, pp. 384-387, Mar. 1964

A transistorized pulse generator system for chemical kinetics experiments with a time-of-flight mass spectrometer is described.

Tunnel Diode Pulse Circuits - See 24,849

Multivibrator Pulse Circuits - See 24,741

24,764 NEW PRINCIPLES IN COUNTING FAST PULSE SEQUENCES [in German] by W. Hilberg (Telefunken, Ulm); Nachr.-Techn. Z., Vol. 17, pp. 24-34, Jan. 1964

This report examines how bistable circuits and gates, composed of given elements, must be connected and operated to form counters capable of accepting and storing extremely fast pulse sequences. The new counting principles are first developed with the aid of block circuit diagrams; then the theory is verified by a transistor-circuit suitably constructed. The results obtained were far better than those realized up to now (minimum distance of pulses $T = 2 \times 10^{-9}$ s).

24,765 A TRANSISTORIZED MILLIVOLT DISCRIMINATOR by M. Birnbaum and V. Comanescu (Inst. Atomic Phys., Bucharest); Electronic Engrg., Vol. 36, pp. 110-113, Feb. 1964

A new transistorized millivolt discriminator with series discriminating element is described. The performance of the circuit is analyzed showing sensitivity in the range of 1 mv, input resistance in the order of 5 kΩ, input repetition frequency $\gg$ 100 kc, good temperature stability (threshold variation of about 0.4 per cent for 1°C) without thermostat. The circuit can be utilized as millivolt discriminator, a pulse-shaper amplifier, for single channel amplifiers, etc.

24,766 FAST LOW LEVEL PULSE DISCRIMINATOR by E. De Blust, I. De Lotto (C.I.S.E.) and V. Mandl (Joint Nucl. Res. Ctr., Ispra, Italy); Aug. 1963, 46 pp.; STAR, Vol. 2, pp. 22-23(A), Jan. 8, 1964 EUR 406.e, Avail. from Belgium Am. Bank and Trust Co., N.Y., Acct. No. 121.86; 70 Belg. Fr.

The behavior of the tunnel diode in a fast low-level pulse height discriminator is analyzed. The characteristics of the tunnel diode in fast trigger circuits are studied by plotting the switching waveforms for nonlinear load and variable-input pulse amplitude and shape. The relations between the switching time, the "lambda" pulse, and the hysteresis are considered and extended also to the classical trigger circuits. As a result of the analysis a discriminator circuit has been developed after an investigation of the different bias circuits. The lowest threshold level is about 2 mv and the input range is higher than 100. The linearity is satisfactory over the whole range, and good temperature stability can be achieved with a simple and cheap thermostat.

OTHER CIRCUITS

24,767 HIGH-VOLTAGE OPERATED EMITTER FOLLOWER FOR SCINTILLATION PROBES [in German] by U. Schneider; Elektron. Rund., Vol. 18, pp. 150, 152, Mar. 1964

A two stage impedance converter equipped with n-p-n and p-n-p transistors for application within a scintillation probe is discussed.

24,768 A SIMPLE DC-AC NEGATIVE-IMPEDANCE CONVERTER, OFFERING SYMMETRICAL N-TYPE AND S-TYPE NEGATIVE RESISTANCE, BASED ON A CIRCUIT OF A.H. MARSHAK by H. Kallman; Proc. IEEE, Vol. 52, pp. 199-200(L), Feb. 1964

A negative impedance converter capable of symmetrical DC or AC, N-type or S-type negative resistance is described. The circuit is a modification of A.H. Marshak's [Electrical Engrg., Vol. 85, pp. 348-351, 1963]. The battery voltage is split into two equal halves, removing (with a residue of < 0.2 v) the DC voltage between the output terminals which would generally require a DC blocking capacitor in series with the external circuit and make the negative resistance usable for AC only. The split also makes the circuit symmetrical. Biasing of the two transistors in the circuit is accomplished by using the forward drop across a Si diode, separating the dual function of one resistor that would otherwise provide base-bias voltage and also determine the negative terminal resistance. Open-circuit-stable and short-circuit-stable terminal sets can be used in this circuit.

24,769 FERROMAGNETIC RESONANCE-TUNED MICROWAVE OSCILLATOR by G. Thiess, J. Wrenn and O. Drefke (Texas Instr.); Proc. IEEE, Vol. 51, pp. 865-866(L), May 1963

The use of an yttrium-iron-garnet (YIG) band-pass filter to close the feedback loop in a Pierce-type oscillator so as to control the frequency is described. A change of approximately 30 eorsteds in the externally supplied magnetic field tunes the oscillator over a 100 Mc band. Feedback energy is coupled through the YIG band-pass filter from the collector to the base of a type TIX2000 transistor.

24,770 OSCILLATING CRYSTALS FOR FILTER SYSTEMS [in German] by R. Bechmann (USAESRDL); Arch. Elektr. Uebertragung, Vol. 18, pp. 129-136, Feb. 1964

The properties of quartz crystals for electrical filter networks in the range 60 kc to 100 Mc are considered. The knowledge of the data of the equivalent electric circuit and freedom from unwanted modes in a specified frequency range are the essential conditions for filter crystals. At low frequencies, the unwanted modes are produced by coupling between various modes while for high frequency thickness modes, the unwanted modes are due to inharmonic overtones. For thickness shear modes of plates with a diameter-thickness ratio greater than 40, the unwanted modes are a function of the electrode radius which also determines the data of the parameters of the equivalent electric circuit. Curves for thickness modes operating in the range 10 to 100 Mc, show the electrode-diameter necessary for the suppression of unwanted modes to 40 db and the resultant motional capacitance and resistance.

Avalanche Diode Noise Generators - See 24,571

24,771 TEMPERATURE EFFECTS IN LOW-LEVEL TRANSISTOR CHOPPERS by J.H. Simpson; Solid State Design, Vol. 5, pp. 22-28, Mar. 1964

The effects of temperature changes on the ON and OFF errors of transistor choppers are considered in some detail, and criteria governing the transistor and circuit parameters for low-level operation are deduced. In addition to the requirement of leakage current to reduce the OFF error, the analysis indicates the importance of large forward current gain (h_{FE}) and moderately large reverse current gain in minimizing the ON error. Experimental results for two germanium and two silicon transistor types, obtained in a balanced circuit over a 20° to 45°C ambient temperature range, are presented. The best of these has an equivalent input drift of 7 μv over the above temperature range when the source resistance is 5.6 kΩ. With crude temperature control the error could be reduced to less than 1 μv.

24,772 FIELD EFFECT TRANSISTORS AS CHOPPERS by L. Fattal; Semicon. Prod., Vol. 7, pp. 13-18, Apr. 1964

The utilization of field effect transistors as choppers for low level dc amplification is described. Errors and methods of compensating for them are discussed. Preliminary theoretical and experimental results compare favorably. Theory indicates that a field effect transistor chopper has no dc offset voltage, nor any variation of transients with temperature. In experimental tests, such a chopper was found to have drifts within ±3 microvolts over the range from 30° to 55°C for source impedances of 500 and 5600 ohms. Finally, a comparison with bipolar transistor choppers and mechanical choppers is made.

24,773 SCR AND ZENER DIODE PROVIDE TIME DELAY by J.A. Means (Pacific Missile Range); Electronic Design, Vol. 12, pp. 73-74, Mar. 30, 1964

A circuit using an SCR and Zener diode in place of a relay and that provides time delay before power is applied to a load is described. With a 24 volt supply and a 500 ma load there is a 1 volt drop across the SCR and a 10 second time delay.

24,774 TRANSISTOR LINEAR DELAY CIRCUIT by B. Nag (Jadavpur U., Calcutta) and R. Krishna (Indian Statistical Inst., Calcutta); J. Electronics and Control, Vol. 16, pp. 349-356, Mar. 1964

A transistor delay circuit is described. The operation of the circuit is based on the principle of discharging the timing capacitor of a monostable multivibrator through a constant current device consisting of a transistor operated in the common-base mode. The circuit generates a rectangular pulse whose duration is directly proportional to a dc control voltage over a large range. It also generates a linear run down voltage having a good degree of linearity. The range of pulse duration obtainable is large. The speed of the linear sweep is continuously variable within a certain range.

24,775 SEMICONDUCTOR TIME-DELAY CIRCUITS by J.J. Pinto (Pinto-Everett Edgcumbe); Electronic Engrg., Vol. 36, pp. 166-169, Mar. 1964

The semiconductors available in the UK are surveyed with the particular requirements of process timers in view. The unijunction transistor is discussed in detail as the semiconductor best suited for use in time-delay circuits and its wider adoption and cheaper marketing are urged.

Square Wave Generators - See 24,736

APPLICATIONS OF SOLID STATE DEVICES

COMMUNICATIONS TYPE APPLICATIONS

24,776 DESIGN FOR TV MINIATURIZATION by R.S. Hiatt (Cohu Electronics); Sys. Design, Vol. 8, pp. 44-45, Apr. 1964

A compact TV camera having 3" diameter, 12" average length, light weight (7.5 lbs. with 4:1 zoom lens), and sturdiness (up to depths of 250 feet of water in standard array) is described. Power consumption is reduced by placing the vidicon filament in series with the focus coil, which gives a 47-gauss focus field with a 95 ma current.

24,777 R.F. AND I.F. STAGES OF A TRANSISTOR A.M. RECEIVER WITH EXTENDED A.G.C. RANGE by R.E. Brown (Mullard Appl. Res. Lab.); Mullard Tech. Commun., Vol. 7, pp. 283-286, Mar. 1964

The RF and IF stages of a transistor AM receiver with extended AGC range are described. Because the receiver is primarily intended for mains operation, an external aerial is likely to be used. Thus a greater degree of AGC is required. The circuit described has an AGC range of 76 to 80 db with a signal-to-noise ratio of 20 db at 240 μv/m, and provides satisfactory results with an external aerial.

24,778 FM PREAMP USES VHF FERRITE TRANSFORMER by G. Costa (Johns Hopkins Appl. Phys. Lab.); Electronic Design, Vol. 12, p. 51, Feb. 3, 1964

A circuit using a ferrite core transformer with a low noise, high gain transistor comprising a one stage preamplifier for the 88-108 Mc FM band is described. Tuning is accomplished by adjusting the primary turns of the transformer and the center frequency may be varied by an adjustment of the emitter current.

24,779 TRANSISTORIZED VHF COMMUNICATIONS SET; Sys. Design, Vol. [illegible], p. 33, Apr. 1964

The ECI 1kw transmitter/receiver combination is described. All solid-state (except for high power level RF stages), it occupies only 2.3 cubic feet. The transmitter is designed to handle either single or multi-channel transmissions, voice or high speed data in both AM and FM modes without an adapter and covers a frequency range of 225 to 400 Mc. It is designed for broad applications where reliability, weight, and size are important factors.

24,780 TRANSMITTER FOR SATELLITE GROUND STATION by H. Goldman, [illegible]. Graham and L. Gray; Electrical Commun., Vol. 39, No. 1, pp. 80-88, 1964

The 240-channel, 10 kw transmitter used with Relay and Telstar is described. The exciter is crystal controlled and makes extensive use of varactor diodes as frequency multipliers. The lower-frequency components for modulation, control, and power are contained in a van near the antenna base. Tuning and control are performed from the van with turn-on of the transmitter being automatically sequenced. Automatic fault protection plus self-clearing automatic reset for temporary failures are provided. The antenna-mounted control circuits remove all radio-frequency drive to the klystron within 10 microseconds after a fault occurs and maintain this condition long enough for the power to be shut off at the van. Solid-state components throughout the transmitter permit substantial reduction in size and increase reliability.

24,781 TRANSISTORIZED 4 W TRANSMITTER FOR 8.315 Mc/s; Electronic Applic., Vol. 23, No. 4, pp. 136-146, 1962-1963

A 4 w transmitter with economical power requirements is described for operation in the 8.3 Mc region. Design procedure is based on the y-parameters of the AUY10 transistor. For operation at the international 8.364 Mc distress frequency, a crystal-controlled oscillator stage could be used. This can be replaced by a grounded-base feedback oscillator for general telegraphic use. The design procedure is suitable for transistorized transmitters operating at other frequencies between 2 Mc and 10 Mc and at higher powers.

24,782 SUPERVISION OF THE CENTRAL SWITCHING EQUIPMENT [in German] by H. Bauer and O. Kneisel (Siemens and Halske); Entwicklungs-Ber., Vol. 26, pp. 47-50, Dec. 1963

In electronically controlled telephone switching systems special importance is placed on supervision of centralized equipment. In order to enable the system to continue operating without interruption, supervision must be particularly quick and reliable, i.e. it must be automated. With these viewpoints in mind the principles and methods for recognizing, localizing and eliminating faults are dealt with. Supervision of the centralized equipment for the ESM System II, Munich-Farbergraben, is described.

24,783 OPTIMUM DESIGN OF FOUR-STAGE SWITCHING SYSTEM by H. Akimaru and K. Iida (NTT); Rev. Electr. Commun. Lab., Vol. 12, pp. 174-190, Mar.-Apr. 1964

Methods are investigated for the design theory of a 4-stage switching system. Special attention is given to the optimum division of outgoing trunk groups, and the optimum traffic capacity of a switching frame. The optimum conditions which minimize the total cost of the switching system under a given service condition are considered. The derivative of Erlang's B formula is applied to the trunk division. As for the frame traffic capacity, the derivative of inner blocking probability of the frames is used. Examples of the optimum design are presented concerning some practical models.

24,784 TRAFFIC MEASURING EQUIPMENT [in German] by H. Hochmuth and G. Knopf (Siemens and Halske); Entwicklungs-Ber., Vol. 26, pp. 61-65, Dec. 1963

The load on the switching members in the speech path network and the traffic behavior of the markers in a telephone system are determined by measuring equipment that operates on the scanning principle. Proper time sequence of all measuring processes is controlled centrally. Intermediate storage of the measured values up to the time the data is made available at quarter hour or hour intervals by a page printer, is effected in a ferrite core storage well known from the data processing field.

24,785 6 Mc/s TRANSISTORIZED SYSTEM FOR 1.2/4.4 mm COAXIAL PAIRS [in French] by R. Belus, M. Toutan, R. Petit-Jean and L. Giraud (Ctr. Natl. d'Etudes des Telecommun.); Cables and Transmission, Vol. 18, pp. 195-210, Apr. 1963

In view of the more and more extended use of 1.2/4.4 mm coaxial pairs in long-distance lines, a 6 Mc transistorized carrier-current system has been developed by the French Posts and Telecommunications Administration. After an analysis of the involved principles, the latest results obtained in the manufacturing of coaxial paris are given. A description follows of the main parts of the system, more particularly of the line amplifier. The arrangement of the intermediate repeater units is described, as well as the way in which they are installed in underground chambers or protected by cast iron boxes and subsequently buried.

24,786 A PHASE MODULATION DATA TRANSMISSION SYSTEM FOR USE OVER THE TELEPHONE NETWORK by A.P. Clark (Brit. Telecommun. Res. Ltd.); J. Brit. IEE, Vol. 27, pp. 181-195, Mar. 1964

A synchronous system is described which transmits binary-coded digital-information at 750 or 1500 bauds over normal telephone circuits. It uses a phase-modulated carrier of 1500 c/s and both sidebands are transmitted. The receiver employs differentially-coherent detection to overcome the one serious weakness of coherent detection, which is the low tolerance of the latter to the frequency modulation effects sometimes experienced over telephone-carrier circuits.

24,787 A NEW LOOK FOR THE OLD TELEGRAPH by R.K. Andres and L.P. Correard; Electronics, Vol. 37, pp. 85-90, Mar. 23, 1964

An electronic system to speed the relay of telegraph messages, automatically correct errors, store messages, and bill customers is described. Messages enter the system through input buffer storage units which hold each character of the message since the teleprinter equipment is slow speed. Then the messages are dumped into a special RCA real-time computer where they are examined for destination and priority and switched to the proper outgoing channel. Magnetic cores, drums, and tapes are used for storage.

24,788 MASERS FOR THE TELSTAR SATELLITE COMMUNICATIONS EXPERIMENT by W.J. Tabor and J.T. Sibilia (NASA, Goddard Ctr.); in Telstar I, Vol. 3, pp. 1863-1886, June 1963; STAR, Vol. 2, p. 130(A), Jan. 23, 1964

The design and characteristics of ruby traveling-wave masers operating at 4 Gc are discussed. These masers, characterized by an average gain of ≈ 35 db over a bandwidth of 25 Mc, are equipped with waveguide input transmission lines, rather than previously employed coaxial cables. This change results in an overall noise temperature of 3.5°K for these devices, rather than the 10°K exhibited by earlier masers. The maser noise temperature now closely approximates sky temperatures, which set the ultimate limit on earthbound receiver sensitivity. The improvements to be had by further reduction in amplifier noise are therefore almost negligible. A less well known maser property, i.e., its freedom from distortion, even when driven well into gain saturation, is discussed.

24,789 LASERS FOR COMMUNICATIONS AND OPTICAL RANGING by G. F. Smith (Hughes Res. Labs.); in Light and Heat Sensing, AGARD, Paris, pp. 221-234, 1963, Contract AF 33(616)-8233; STAR, Vol. 2, p. 917(A), Apr. 8, 1964

The three key properties of the laser light source - brightness, focusability, and monochromaticity - enable it to transmit information efficiently to a distant point even in the presence of other undesired radiation "noise," because that noise can be rejected by a filter. In a one-way communications link with constant-aperture diffraction-limited antennas, the fraction of transmitted power that is received is proportional to the square of the frequency. Signal fluctuation noise, however, increases linearly with frequency, so the S/N ratio improves only linearly with frequency. At optical frequencies, aiming problems are likely to limit the useful degree of beam collimation; thus, on the basis of bandwidth per transmitted watt, a laser space-communications link will be competitive with, but not drastically superior to, a futuristic microwave space link. The high-power pulse performance of ruby lasers is promising for optical ranging. Although rudimentary ranging systems have operated only at several kilometers, it now appears feasible to range off the moon.

24,790 LASERS FOR RANGING APPLICATIONS by E. Kornstein (RCA); in Lasers, RCA, Camden, N.J., 1963, pp. 16-19; STAR, Vol. 2, p. 50(A), Feb. 23, 1964

A prototype laser ranging system is discussed along with the basic considerations of laser ranging. The prototype unit, as packaged includes a sighting telescope, transmitter, and receiver optics. A review is given of early ranging systems, and the generation of single pulses is discussed. A technique for controlling laser output is also given, along with the range equation developed for laser ranging systems.

24,791 SOLID-STATE LIGHT SOURCE FOR DISTANCE-MEASURING EQUIPMENT by A. Harrison (U. Washington); Proc. IEEE, Vol. 52, p. 101(L), Jan. 1964

The properties necessary for a laser source to be used with phase comparison electronic surveying instruments are summarized. It is concluded that although at the present time no advantage would be gained from the use of a laser in such instruments, with the advent of new solid state devices the application should not be overlooked.

COMPUTERS and OTHER DATA HANDLING SYSTEMS

DIGITAL COMPUTERS

24,792 POSSIBLE USES OF LASERS IN OPTICAL LOGIC FUNCTIONS by C. J. Koester (Am. Optical); Proc. 1963 Pacific Computer Conf. IEEE, Pasadena, Calif., Mar. 15-16, 1963, pp. 54-62

The principles of the laser are reviewed and a few ways in which lasers could provide optical logic functions are suggested. The use of light is attractive for information processing techniques because: the high frequency holds promise for high bit rates, transmission of light is practically free from ordinary inductive and capacitive effects, times of interaction with matter can be short, high density of storage is possible, and lens systems are convenient for parallel processing of information. A discussion of a typical optically pumped 4 level system, which utilizes the neodymium ion as the active element, is presented. A laser quenching experiment is described which demonstrates the ability of one light beam to influence another and thereby perform logic functions. The time has been shown to be at least as fast as a microsecond. Further studies with fast rise time Q-switched lasers should help to define the limiting switching time. Nonlinear effects in dielectrics and laser pumping effects are also briefly described.

Micro-Logic Circuits - See 24,793

24,793 SOLID LOGIC TECHNOLOGY: VERSATILE, HIGH-PERFORMANCE MICROELECTRONICS by E.M. Davis, W.E. Harding, R.S. Schwartz and J.J. Corning (IBM); IBM J. Res. and Dev., Vol. 8, pp. 102-114, Apr. 1964

A new microelectronics packaging technique, called Solid Logic Technology (SLT), utilizing silicon planar glass-encapsulated transistors and diodes, and graphic arts techniques for producing high-quality, passive components having tight tolerances is described. The result is a process permitting the low-cost realization of a variety of versatile, high-performance circuit modules. The salient features of SLT are described: the unique form of the semiconductor devices, the module fabrication process, and some performance results. In addition, insight is provided to the range of components that may be fabricated with this technology, i.e., inductors, capacitors and high-power transistors. Examples are shown of specific high-speed, high-density and complex circuit packages.

24,794 CIRCUITS WITH DIRECT COUPLING by L.V. Kutukow and D.I. Obidin (Wright-Patterson AF Base); Sept. 27, 1963, 33 pp., FTD TT62 1869, Trans. from Elektron. Vychislit. Mash., pp. 1-39, 1962; U.S. Gov. Res. Rep., Vol. 39, p. 39(A), Apr. 20, 1964 AD 428 628 OTS $3.60

All transistor computer circuit applications can be divided into two groups: saturated circuits and circuits with limited saturation. In many cases, the first type is more promising and requires fewer components; the second type operates faster. With regard to direct coupled circuits operated under saturated conditions, all of the requirements of transistors operating in saturation circuits with R and RC coupling circuits, are applicable to the former circuits also. In addition, new requirements inherent only to this type of circuit are in effect. In this text all these requirements are considered briefly, and the results of the measurements of some parameters of locally produced transistors P 403 + P 413 and the testing of these transistors in the simplest logical circuits are presented.

24,795 LOGIC DESIGN WITH REED RELAY MODULES; Systems Des., Vol. 8, pp. 34-37, Apr. 1964

The application of the Clareed Logic Module (a combination of glass-encapsulated Clareed switches enclosed in multiple-wound coils and assembled as a module) is discussed. Each module may provide AND, INCLUSIVE-OR, or EXCLUSIVE-OR logic. Only two are needed for a binary half-adder (no previous carry) which needs no complementary input. Other module circuits are a 3-Input Complex Logic Element, a Binary Full Adder/Switch, a Four-Stage Binary Adder and a Binary Coded Full Adder/Subtractor.

24,796 A BI-DIRECTIONAL DECADE COUNTER WITH ANTICOINCIDENCE NETWORK AND DIGITAL DISPLAY by A.F. Tassinari (Paoletti, Italy); Electronic Engrg., Vol. 36, pp. 173-177, Mar. 1964

A reversible counter is described which consists, basically, of four self-gating flip-flop binary divider stages in cascade, with the correct feedback to form a decade counter. An anticoincidence network is included and semiconductor devices are used throughout.

24,797 LOCKED-PAIR LOGIC NEARS GIGACYCLE RATE by A. Corneretto; Electronic Design, Vol. 11, pp. 4-7, Dec. 20, 1963

Balanced pairs of tunnel-diodes that can provide an 800 Mc phase rate in a four-phase, 10-circuit microwave counter are described. Their successful microwave operation is achieved by a coaxial package, which minimizes circuit parasitic induction and permits current gains of 20 in the tunnel-diode circuits as well as by stripline power dividers, which closely control the amplitude and phasing of sinusoidal excitation signals to ease tolerance requirements on the diodes and their resistors. Sylvania believes that with integration techniques they could increase their achieved phase rates to a maximum of 2 Gc and develop a complete computer.

24,798 SHIFT REGISTERS SIMPLIFY COUNTING; Electronic Design, Vol. 12, p. 56, Apr. 13, 1964

Modulo-10 (a basic Fairchild integrated circuit) high-speed counters are described. Five double range stages of storage elements are connected as an ordinary shift register; the outputs of the 5th stage are fed back to the inputs of the 1st with a cross-over. Advantages are an increase in speed over binary counters and design simplicity.

24,799 LIGHT-SENSING SCRs MAKE SIMPLE RING COUNTER by R. Carvajal (Texas Instr.); Electronic Design, Vol. 12, p. 50, Feb. 3, 1964

A circuit using a light-sensitive silicon controlled rectifier stage which operates as a low-frequency ring counter is described. Circuit values and operational performance are given, and suggestions for improvement in system efficiency are proposed.

24,800 FULL BINARY ADDER INCLUDING NEGATIVE RESISTANCE DIODE by B. Rabinovici and C.A. Renton (RCA); U.S. Pat. 3,125,674, Issued Mar. 17, 1964

A binary adder featuring the use of a negative resistance diode permitting reliable operation, low power dissipation, and high switching speeds, as well as circuit simplicity and low cost construction, is described. The adder circuit, essentially an impedance bridge, one arm of which includes a negative resistance diode such as a tunnel diode, is discussed and experimental suggested component values are given.

24,801 ALL-MAGNETIC SHIFT REGISTER SCHEME STUDIES by E.K. Van De Riet (Stanford Res. Inst.); July 1963, 52 pp., Contract Nonr271200; U.S. Gov. Res. Rep., Vol. 39, p. 77(A), Mar. 5, 1964 AD 419 410 OTS $5.60

A method of cataloging and synthesizing all-magnetic shift register circuits is described. The cataloging procedure provides a consistent organization of known schemes, and the synthesis process generates all possible shift register schemes in a given category. The scheme used related to the sequence of switching of the various elements of particular configuration to accomplish shifting in a register. The synthesis process was applied to three different con-

urations of magnetic toroids and wire coupling loops. Two new schemes re synthesized in addition to two that were already known. Applications of s synthesis technique to more complicated configurations should result in re interesting and more practical circuits.

,802 MAGNETIC CONTROL CIRCUITS by T.H. Crowley and U.F. Gianola ll Labs.); U.S. Pat. 3,126,531, Issued Mar. 24, 1964

single-core magnetic shift register is described. The device consists of a lad--like core with two "advance pulse" windings, each passing through alter-e "rungs," in addition to an input write and output winding. The magnetic mains in the device are such that when it goes through a cycle of four pulses, plied alternately to each of the advance windings, a bit of information in e form of a domain arrangement moves one position down the core. Addition-windings gated by the pulse sources provide readout at any position in the ister during a shift cycle. A new bit can be entered during each cycle. In-mation reaching the end of the core is shifted out of the register.

,803 THE SYNTHESIS OF CYCLE CODE GENERATORS by P.E.K. Chow d A.C. Davies (GE); Electronic Engrg., Vol. 36, pp. 253-259, Apr. 1964

r digital frequency division and code generation, feedback shift registers ve a number of advantages over the better known techniques using binary unters. Methods of designing feedback shift registers are explained and a w method is proposed. This method leads to the design of a similar but more neral circuit arrangement than the feedback shift register, capable of a der field of application and not limited to the generation of chain codes.

,804 STABILITY CALCULATIONS FOR A SHIFT REGISTER WITH RECTANG-AR FERRITES AS STORES [in German] by H. Stegmeier and R. Zscherpel ech. Hoch., Stuttgart); Arch. Elektr. Uebertragung, Vol. 18, pp. 249-254, r. 1964

shift register which uses one ferrite core per bit for storage and one capacitor r intermediate storage is described. It is shown how the stability can be con-derably improved by the interposition of an inductance between core and ca-acitor and how the inductance of this choke and the data of the other circuit mponents must be chosen for a specific application. For this calculation a mple method is used which also allows a calculation of the stability of the ift register.

1,805 DYNAMIC OPERATION OF THE IN-LINE CRYOTRON IN BISTABLE RCUITS by A.E. Brennemann, H. Seki and D.P. Seraphim (IBM Watson Res. r.); Proc. IEEE, Vol. 52, pp. 228-238, Mar. 1964

e dynamic operation of the in-line cryotron was tested by performing pulse easurements on individual devices and also by using the device in free-run-ng closed-loop oscillators (similar to shift register). The gain of the device currently insufficient to permit bit transfer from one stage of the oscillator the next in less than 25 nsec. The slower propagation is shown to be assoc-ted with the slow transition of resistance from the superconducting to the rmal state and also from the normal to the superconducting state. The cryo-on switching time is dependent upon the magnitude of the applied magnetic eld. The times for switching resistance obtained from the pulse measurements e applied to the analysis of the dynamically operating closed-loop register. e maximum oscillating frequency of 5 Mc for a four-stage closed register was edicted by the analysis and is shown to be in good agreement with the experi-ent. A similar analysis, using the same cryotron limitations, shows the maxi-um frequency for a two-stage closed-ring register to be essentially the same s that for a four-stage register. The large incremental gains anticipated are ot obtainable when the device is operated at frequencies of about 10^7 cps or reater. This limitation arises from the requirement of supplying bias at $0.7\,H_c$ nd preferably $0.5\,H_c$ to allow for a fast turnoff of the device. Consequently, e static gain is not sufficient to provide a large overdrive for a fast turn-on f the device.

4,806 FUTURE DEVELOPMENTS IN LARGE MAGNETIC FILM MEMORIES y J.I. Raffel (Lincoln Lab.); J. Appl. Phys., Vol. 35, pp. 748-753, Mar. 1964

ome judgments are formulated about memory organization, fabrication tech-iques and cell structures which are generally applicable to improving the peed-cost ratio of static magnetic storage devices. More specifically, for agnetic films, techniques for realizing simultaneously high bit density and imple fabrication are discussed. Based on very rough estimates, it is proposed hat for a million-word memory, a cost reduction of almost two orders of mag-itude over present day stores with speeds of approximately one microsecond or ess should be feasible with films. Alternative cell configurations and areas of ngineering compromise are discussed. Experimental results with etched cells aving dimensions as small as 2 mils (0.05 mm) for both quasiclosed and open tructures have been obtained. Both multiword readout and a method for shar-ng sense amplifiers by "band switching" are considered.

24,807 LOW-CURRENT, HIGH-SPEED MAGNETIC MEMORY ARRAY UTILI-ZING EVAPORATED MATRIX WIRING by T.J. Matcovich, W. Flannery, W. Luciw and A.A. Adomines (UNIVAC); J. Appl. Phys., Vol. 35, pp. 760-761, Mar. 1964

Planar, thin film magnetic memory arrays of 4x4 and 64x24 elements have been fabricated from evaporated matrix wiring and insulating layers. Four metallic and three insulting layers were evaporated sequentially in a vacuum chamber without breaking the vacuum. The magnetic element is an electroplated ternary alloy of nickel-iron-phosphorus 0.13 mm (0.005-in.) in diameter and a few hundred A thick. The film has an anisotropy field of about 1 oe and switches in 10 nsec with an applied word drive current of 35 ma. Sense and cancellation lines and dummy bit lines are used to cancel interwire coupling. Disturb tests were performed with up to 10^4 disturb pulses being applied along the easy axis. The outputs from films with $H_c/H_k \approx 2$ were decreased by less than 10 per cent when disturbed in this manner. An evaporated memory array made with highly inverted films may be usable as a high-speed, low-current memory storage device.

24,808 NDRO MAGNETIC FILM MEMORY MODE USING CREEP AND BOUNDARY DISPLACEMENT SWITCHING by J.H. Hoper (Iowa State U.); J. Appl. Phys., Vol. 35, pp. 762-764, Mar. 1964

A new switching technique for thin magnetic films of Permalloy was investigated. Orthogonal ac fields were used instead of the usual pulse switching fields. Two variations of the transverse field were tried with $\omega = 2\pi \times 10^6$ rad/sec: $h_T = H_T \frac{1}{2}(1 - \cos\omega t)$ and $h_T = H_T \sin(\omega/2)t$. The longitudinal fields (easy direction) were $h_L = H_L \cos\omega t$ or $-H_L \cos\omega t$; h_L or $-h_L$ was used depending on which remanent magnetic state of the film was desired. The time display of the vector sum (Lissajou pattern) of h_T and h_L formed a straight line or a parabola for the two transverse drive methods. With the correct combinations of h_T and h_L, the film would switch with both fields applied but would retain the previous state with only one of the two applied. The state of the film was detected by applying the nondestructive h_T and observing the phase of the output from a sense winding. This switching mode appears to have utility in large, word organized memories.

24,809 A PREWIRED STORAGE UNIT by I.R. Butcher (P.O. Res. Labs., Melbourne); IEEE Trans., Vol. EC-13, pp. 106-111, Apr. 1964

A flexible and economical form of prewired semi-permanent storage with a capacity of 4096 words of 40 bits is described. A cycle time of 1 μsec can be readily achieved. The information is prepared by threading wires onto plates which are then placed over an array of ferrite rods. The sense in which a wire passes around the rod determines whether a current pulse in the wire will induce a positive or negative voltage in an output winding wound around the rod. Eight plates, each with 512 words, can be used. The plates can be removed from the store, allowing the information held in the store to be changed quickly and easily. The application of this form of storage to the design of sequential switching circuits is briefly discussed.

24,810 A TECHNIQUE FOR ACHIEVING HIGH BIT PACKING DENSITY ON MAGNETIC TAPE by J.E. Gillis (Lincoln Lab.); IEEE Trans., Vol. EC-13, pp. 112-117, Apr. 1964

A technique is described for achieving very high bit packing densities, with low error rates, on magnetic tape. This technique uses envelope orthogonal signals to encode binary data during the recording process, and matched filters are used to recover these signals during playback. The experimental system constructed to evaluate the technique is described and a discussion of the experimental results is presented.

24,811 DESIGNING A SMALL CORE MEMORY FOR ECONOMY AND RELIABILITY by B.D. Jimerson; Solid State Des., Vol. 5, pp. 31-34, Apr. 1964

The principles dictating the design of core buffers which are required to operate over large ambient temperature conditions are conveniently epitomized by means of an example. The memory described, a 240 bit word select core buffer, was developed for use as a temporary storage medium between the primary computer and a high speed mechanical printer. The system incorporates several unique circuits to effectuate a reliable and economical design.

24,812 CARDS FORM BIGGEST MEMORY; Electronics, Vol. 37, p. 52, Feb. 14, 1964

RCA's Race Computer which can store up to 5.4 billion characters on $16 \times 4\frac{1}{2}$ magnetic cards for storage in eight magazine retrieval units is described. Two of the units can be connected to a read-write station and four of these 16 magazine complexes can be connected to each of two control units. Each card is divided into 64 separately addressable bands of two tracks each with 166,400 characters per card.

24,813 A TERNARY MEMORY ELEMENT USING A TUNNEL DIODE by F. Salter (Argonne Natl. Lab.); IEEE Trans., Vol. EC-13, pp. 155-156(L), Apr. 1964

A three-state memory now in development at Argonne is discussed. It uses a

tunnel diode which oscillates but is biased by a capacitor to maintain the three dc states stable externally. A method is also described which can transfer numbers from one memory to another in less than 20 nsec.

24,814 A SURVEY OF HIGH SPEED RANDOM ACCESS STORAGE TECHNIQUES by I.R. Butcher (P.O. Res. Lab., Melbourne); Proc. IEEE, Austrl., Vol. 25, pp. 81-89, Feb. 1964

The rapid growth of computers and other digital data handling equipment has been very dependent on the development of suitable devices for the storage of digital information. The ferrite core has been, and still is, the most important of these. The two basic store configurations, coincident current selection and word organized or linear selection are discussed with reference to core stores in particular, although they are applicable to all storage devices employing loop hysteresis. More recent developments, such as ferrite plates, multi-apertured cores and thin film devices both magnetic and cryogenic are briefly discussed and compared with the core. Reference is made to stores allowing non-destructive readout and to the associative store from which data can be read without knowledge of its location. Finally, the current state of the art is reviewed and probable future trends indicated.

ANALOG COMPUTERS AND OTHER DATA SYSTEMS

24,815 "WORST CASE ANALYSIS" IN ANALOG CIRCUIT DESIGN by P.A. Milone and F.J. Sposato; Electronic Ind., Vol. 23, pp. 78-81, Mar. 1964

An equipment design approach which will give long term reliability under the worst possible operating conditions is discussed. Three basic design areas are considered: circuit analysis, component derating, and quality assurance. With this approach, circuit equations are first established for open loop gain, stability, power dissipation, etc., and then end-of-life component tolerances, found from vendor data and testing, are inserted as parameters. This approach is basically digital, but it can also be used for analog circuits. It is illustrated with an application for transistorized power supplies, which thereby achieved Mean Time Between Failure rates in excess of 100,000 hours. This approach also shows that positive feedback is a closed loop, current feedback and the use of devices for compensation of temperature drift are poor practices when long term reliability is needed.

24,816 ANALOG SIMULATION TECHNIQUES by R.A. Heartz (GE); IEEE Spectrum, Vol. 1, pp. 221-230, Mar. 1964

Analog simulation techniques which make it possible to test and evaluate proposed circuitry in the conceptual stage are described. Scaling factors can be chosen for each simulation problem to provide the required data. Time-expansion simulations permit the study of the many variables in a complex electronic system, while time-compression simulations provide information in a fraction of the time required for a real-time evaluation. A description of the components of an analog computer system is presented and applications of simulation techniques in the study of a phase-locked receiver and an FM receiver are discussed.

24,817 OPERATIONAL AMPLIFIER CIRCUITS by J. Embree (Computer Dynamics); Systems Des., Vol. 8, pp. 10-15, Apr. 1964

Operational amplifier circuits are discussed with regard to analog computing circuits, process simulation/control circuits, and test instruments. Included are diagrams of a "first-order lag", a retarded differentiator, constant current and voltage generators, a high-speed programmable supply, low-current amplifiers, an oscilloscope preamplifier, a stabilized-follower amplifier/monitor, a single-ended unbalanced-input bridge, and an operational null bridge.

24,818 REVERSIBLE OPERATIONAL AMPLIFIER by H. Ye. Pukhov; in Rev. Operational Amplifier and Characteristics of Transportation Network, pp. 1-6, Jan. 3, 1964; STAR, Vol. 2, p. 550(A), Mar. 8, 1964 JPRS-22607, OTS-64-21211; $0.50

Diagrams of the electric circuits and analyses of the operation of the following are included: (1) irreversible operation amplifier; (2) reversible operational amplifier; and (3) conventional designations of the reversible solution elements - multiplier-divider, inverter, and integrator-differentiator. The mathematical operations are realized by means of an electronic simulating device if, along with the elements of directed action, there are elements for which the feeding of voltages to any of the poles would cause the appearance of corresponding voltages at other poles. These elements can be obtained on the basis of the proposed reversible operational amplifier.

Operational Amplifiers - See 24,713

24,819 A CIRCUIT FOR FINDING THE ROOT-MEAN SQUARE by R. Entenmann (Genl. Dynamics/Electronics); Proc. IEEE, Vol. 52, p. 193(L), Feb. 1964

A circuit that can determine the square root of the sum of the squares of two variables is described. This circuit has been adapted to find the magnitude of the radial distance from the center of a cathode-ray tube display to a deflected spot when only horizontal and vertical signal voltages are available. The circuit uses five diodes, seven resistors and a voltage supply, and is accurate to ±1.5 per cent.

24,820 SOLID STATE ANALOG-TO-DIGITAL CONVERTER AND ELECTRON AND HOLE INJECTION BY A METAL-DEPLETION LAYER CONTACT by V.J. White, R.E. Onley, P.G. Sedlewicz and C.R. Kannewurf (Northwestern U.); Memo No. 400, Dec. 30, 1963, 1 v., Contract NOw62 0749d; U.S. Gov. Res. Rep., Vol. 39, p. 129(A), Apr. 20, 1964 AD 428 846 OTS $3.60

This is the final report on research and development directed toward determining the feasibility of fabricating a solid-state analog-to-digital converter (or ADC). This research is based on the movement of the depletion region of a reverse biased p-n crystal of the silicon and the detection of this movement.

24,821 ON THE GRAY READING OF BINARY CODED DISKS by P.M. Will (AMF Brit. Res. Lab., Reading); J. Sci. Instr., Vol. 41, pp. 177-178, Mar. 1964

This note shows that it is possible to obtain a Gray coded output from a binary coded disk by a suitable redistribution of the reading cells.

24,822 USE OF OPTICAL MASERS IN PRINTERS AND DISPLAYS by H. Fleisher and W. Kulcke (IBM); Rept. No.3, Oct. 6, 1963, 79 pp., Contract DA36 039AMC00118E; U.S. Gov. Res. Rep., Vol. 39, p. 124(A), Apr. 20, 1964 AD 428 610 OTS $8.10

Laser technology is developed for computer input-output devices such as display, fast printing, etc., and to prepare a laboratory-type demonstration to indicate the ability to electronically modulate and deflect a light beam. This task is preparatory to further development of a complete laser display system.

POWER and CONTROL APPLICATIONS

24,823 ANALYSIS OF SERIES REGULATORS AS ACTIVE TWO-PORT NETWORKS by R.A. Zakarevicius (U. New South Wales); J. Brit. IEE, Vol. 27, pp. 237-243, Mar. 1964

Regulators for regulated power supplies are here treated as active two-port networks. To characterize the performance, two parameters: the regulation factor $\mathcal{R}$ and the internal impedance Z_{out} are defined for the ideal case of infinite load impedance and zero source impedance of the unregulated side. A general theory is developed and specific circuit arrangements are shown to be particular cases of the general theory. For the simplest series transistor regulator it is found that $\mathcal{R} = h_{rb}$ and $Z_{out} = h_{ib}$, h_{rb} and h_{ib} being standard hybrid parameters of the transistor. A more advanced series transistor regulator is then dealt with and extension of the theory to more complicated cases is discussed. The treatment is from a transistor point of view, but the method is also applicable to vacuum tubes.

24,824 REGULATOR ELEMENTS USING TRANSISTORS by J.W. McPherson (GE Ltd.); Electronic Engrg., Vol. 36, pp. 162-165, Mar. 1964

The shortcomings of the paralleled transistor approach to the design of high power regulator elements are discussed and some new circuit arrangements which can result in the use of fewer power transistors, smaller heat sinks and reduced standing losses are described.

24,825 RAYISTOR COMPENSATES CURRENT GENERATOR by K. Myers (Aero Service); Electronic Design, Vol. 12, pp. 75-77, Apr. 13, 1964

A Raysistor (a photoresistor, whose resistance decreases as light increases) that provides electrically isolated compensation for changes in input voltage in a constant-current generator, is described. The generator feeds 30 ma to a 20-v Zener which regulates V_{CC} in a differential amplifier. Load changes are about 10 per cent and V_{CC} remains 20 v ± 1 mv over a wide temperature and input voltage range.

24,826 CURRENT REGULATOR FOR A 10,000-A DC 7.5-MW MAGNET POWER SUPPLY by B.H. Smith (Lawrence Radiation Lab.), J.R. Atwood and D.N. Lyon (Wm. M. Brobeck and Assoc.); Rev. Sci. Instr., Vol. 35, pp. 340-352, Mar. 1964

Design and construction details are discussed for a dc current control system

able of a short term stability of a few parts in 10^6 and a long term stability -2 parts in 10^5 when used in conjunction with conventional rotating dc gen-tors powering loads with time constants of approximately 200 msec at levels o 7.5 mw.

er Current Supplies - See 24,678

827 APPLICATIONS OF A GATE CONTROLLED SWITCH IN DC POWER ICUITS by M. Wright (Joseph Lucas Ltd.); Electronic Engrg., Vol. 36, pp. 87, Feb. 1964

ieral circuits are shown using transistors and silicon controlled rectifiers to trol the power delivered to a dc load. Included are circuits for dc power ilifiers, automatic controls of rotating machines, ac voltage regulators, cir-s using mechanical contacts, transducer controls, and circuits for reducing effects of internal feedback.

828 SHORT-CIRCUIT PROTECTION FOR TRANSISTORIZED POWER SUP-ES by F. Sposato and P.A. Milone (Consolidated Avionics); Electronic Des., . 12, pp. 48-49, Apr. 13, 1964

used transistor power supply circuit arranged so that the series pass transis-are forced into saturation when a current surge occurs is described. Satu-on protects the transistors until the input fuse opens to provide full protec-n.

829 STATIC ADJUSTABLE FREQUENCY DRIVES by K.A. Hulstrand (Louis is Co.); Control Engrg., Vol. 11, pp. 57-63, Apr. 1964

con controlled rectifier inverters have made practical static ac adjustable ed drives in which frequency and motor speed are precisely matched to the ut of a reference oscillator. Major advantages are load-insensitive speed trol, particularly in matched multi-motor systems, and minimum long-term t. Reliability and life are also improved by controller static construction the inherent ruggedness of ac motors. Different drive system configurations presented, as well as applications such as a single-motor system for a ma-ne tool spindle drive and a multimotor system on a fiber spinning machine.

830 THYRISTOR CONTROL OF WARD LEONARD DRIVES by B.J. Hodg-; Ind. Electronics, Vol. 2, pp. 105-109, Mar. 1964

ariable speed drive is commonly obtained by using the Ward Leonard system. w this basic system is improved by the use of thyristors (silicon controlled itifiers), is discussed. They enable smooth control of speed, and also speed ulation, to be obtained at high efficiency.

831 STANDARDIZED VARIABLE-SPEED DRIVES USING SEMICONDUCTOR VICES by L.W. Eales; G.E.C. J. Sci. and Tech., Vol. 31, No.1, pp. 21-9 1964

general requirements of industrial variable-speed drives are discussed and different types of drives for both dc and ac motors are considered. Trans-tor/diode and silicon controlled rectifier drives for dc motors are described greater detail together with the necessary control circuits for both unit- and up-drive arrangements. Typical performance characteristics are given and ntion is made of the optional features which may be incorporated in such ves for particular applications. Some typical examples of modern industrial ves of this kind are described.

,832 SCR CIRCUIT A VERSATILE DRIVER OF MANY LOADS by J. Gray, (Argonne Natl. Lab.); Electronic Design, Vol. 12, p. 74, Apr. 13, 1964

universal drive circuit using an SCR and suitable to operate recorder-pen ves, mechanical registers, power relays, or a strobe light, is described. hen the SCR fires, a capacitor discharges through the load.

,833 A SIMPLE PHOTOTRANSISTOR TEMPERATURE CONTROLLER by G. Cockett and R. Harris (Roy. Armament Res. and Dev. Estab., Sevenoaks); Sci. Instr., Vol. 42, pp. 186-187, Mar. 1964

simple phototransistor temperature controller, utilizing the out-of-balance ivanometer deflection from a thermocouple potentiometer to vary the energy out to a low thermal capacity X-ray diffractometer furnace, is described. ecimen temperatures up to 1100°C are maintained constant to ±2°C.

actor Temperature Controls - See 24,852

,834 STREET LIGHTING CONTROLLER USING A PHOTOCONDUCTIVE ELL by G.F. Jeynes and G.J. Thomas (Mullard Appl. Res. Lab.); Mullard ch. Commun., Vol. 7, pp. 271-275, Mar. 1964

sensitive automatic controller for street lighting is described. It switches at edetermined daylight levels rather than at predetermined times, thus catering th for abnormal dark periods at dusk, dawn, or during the day, and for the special needs of (say) tree-lined streets. A delay circuit obviates erroneous switch-off by lightning flashes and other transient illumination. The unit is immune to the results of power failures; and in cost and power consumption also, it compares favorably with conventional clock controllers.

24,835 A TRANSISTOR CIRCUIT FOR XENON FLASH TUBE OPERATION by P.G.M. Dawe (Oxford U.); Electronic Engrg., Vol. 36, pp. 220-221, Apr. 1964

A circuit is described which lights a xenon flash tube from a transistor controlled switch, operated by pulses obtained from a flip-flop and multivibrator. A feature of the transistor control is the application of an auxiliary ionizing circuit to the lamp to maintain a continuous discharge path within it.

24,836 CdS CELL IN LENS' SHUTTER CONTROL TRIGGERS IN 2 Msec; Electronic Design, Vol. 11, pp. 22-23, Dec. 20, 1963

The CdS cell designed for photocell shutter control of the Polaroid 100 camera is described. This new cell has a resistance vs light slope of 0.9, and flat response within a ratio of 1 to 1.10 to different color temperatures of light from 2850 to 6000°K. Adjustment of the time constant of the RC combination of the photocell and Schmitt trigger capacitor controls the shutter with a response of two or three milliseconds.

INSTRUMENTATION

24,837 MAKING ACCURATE MICROWAVE POWER MEASUREMENTS by R. Pramann (Hewlett-Packard); Electronic Ind., Vol. 23, pp. 126-132, Apr. 1964

Equipment and methods used to make microwave power measurements to within 1-1/2 per cent to 3 per cent, depending on conditions, are described. A temperature-compensated meter using two self-balancing bridges and two thermistors is employed to separate the effects of changes of microwave power and changes in the environment. The use of feedback results in a reliable, accurate instrument. The Effective Efficiency of a thermistor mount or the ratio of the substituted dc power in the thermistors divided by the microwave power dissipated in the thermistor mount is obtainable from the National Bureau of Standards. The dual element bolometer mount error and the instrumentation error are discussed.

24,838 THIN-FILM WAVEGUIDE BOLOMETERS FOR MULTIMODE POWER MEASUREMENT by B.M. Schiffman, L. Young and R.B. Larrick; IEEE Trans., Vol. MTT-12, pp. 155-163, Mar. 1964

Thin film bolometers have been developed for measuring the total (unwanted) power that could be transmitted in any or all possible modes and at many frequencies above the normal operating band. The bolometer is a thin metal film which is placed so that it intercepts all the power flowing down the waveguide. When the power in the fundamental frequency is filtered out and only power at higher frequencies remains in the waveguide containing the bolometer, then it can be used to measure the total spurious power emitted by a high-power transmitter above its fundamental frequency band. Measurements have been made up to 15 Gc in S-band waveguides.

24,839 SOLID-BACKED EVAPORATED THERMOPILE RADIATION DETECTORS by R.W. Astheimer and S. Weiner (Barnes Engrg.); Appl. Optics, Vol. 3, pp. 493-500, Apr. 1964

Modern space-borne infrared systems require uncooled detectors sensitive to long wavelength radiation from 8 μ to 40 μ. The thermal detectors, such as thermistor and metal film bolometers, and radiation thermocouples are most practical. It is shown that the thermocouple detector has certain characteristics which make it particularly attractive for space-borne use. Chief among these is the fact that it has inherent dc stability and therefore does not require optical modulation. This permits systems to be designed with no moving parts. A technique is described for the construction of rugged thermocouple and thermopile detectors by vacuum deposition of evaporated materials through masks onto a solid substrate. This technique permits quantity production of complex detector element arrays that can survive and operate in severe military and space environments. A brief theoretical analysis of the performance to be expected from the new design is given and the properties of several configurations which have been fabricated are described.

24,840 A PORTABLE PHOTOINTEGRATING METER FOR USE IN CROPS by J.A. Irvine (Findlay, Irvine Ltd.) and P. Harper (Edinburgh Sch. Agriculture); J. Sci. Instr., Vol. 41, pp. 231-233, Apr. 1964

An electronically operated photointegrator is described. The instrument is portable, compact, robust, light in weight, and not affected by small changes in battery voltage. Response to light intensity is linear between 10 and 800 lux, a range which can be extended upwards with the use of filters. An attempt has

been made to simulate the sensitivity of the green leaf to light for photosynthesis. Records are obtained from a digital register.

24,841 TEMPERATURE MEASUREMENTS USING SMALL QUANTITIES OF CERIUM MAGNESIUM NITRATE by W.R. Abel, A.C. Anderson and J.C. Wheatley (U. Illinois); Rev. Sci. Instr., Vol. 35, pp. 444-449, Apr. 1964

A study is made of the requirements of a mutual inductance system suitable for precise temperature measurements using about one gram of cerium magnesium nitrate. The mutual inductance is measured by a commercial version of the electronic bridge originally proposed by Pillinger, Jastram, and Daunt [Rev. Sci. Instr., Vol. 29, p. 159, 1958]. A discussion of the effects of spurious magnetic materials, of nearby paramagnetic salts, and of the vacuum jacket is given. The linearity and stability of the electronic bridge, as well as the effects of external circuitry, are also discussed. Results are given for the properties of two coil sets with cerium magnesium nitrate thermometers used to test the stability of the bridge and the validity of expressions for mutual inductance obtained in the text. It may be concluded that if solid air can be kept away from the coils, the long term instabilities for a 1-g thermometer lead to errors of about $0.004°K^{-1}$ in 1/T. A comparison between ballistic and 17 cps bridge measurements down to 0.015°K showed that 1/T* as determined by the two methods was the same with an error of less than 0.1 per cent.

24,842 MAGNETOELECTRIC FLOWMETER by V. Cushing (Engrg. Phys. Co.); Rev. Sci. Instr., Vol. 35, pp. 496-499, Apr. 1964

Faraday's law of induction, $E = u \times B$, is the basis for the electromagnetic flowmeter. In such a flowmeter a uniform magnetic induction is established transverse to a flow pipe; a flow of the metered fluid generates a potential difference at suitable detecting electrodes. In this device, the generated potential difference is linearly proportional to volumetric flowrate through the pipe, provided only that the flow velocity profile is axially symmetric. It is pointed out here that a flowmeter can also be designed based on the fact that a moving polarized dielectric generates an effective magnetic moment according to the equation $M = P \times u$. This last equation is formally analogous to the first cited equation describing Faraday induction. It is shown here that one can readily adapt the theory of the electromagnetic flowmeter to analyze the operation of a magnetoelectric flowmeter. In this paper a magnetoelectric flowmeter is described wherein a uniform electric field is established transverse to a pipe through which a dielectric fluid flows; a magnetic induction is generated which is linearly proportional to the volumetric flowrate through the pipe; the induction may be measured with a suitable magnetometer.

24,843 A DEW POINT METER BASED ON THERMOELECTRIC COOLING by O.G. Griffin and C.M. Stringfield (Safety in Mines Res. Estab., Sheffield); J. Sci. Instr., Vol. 41, p. 241, Apr. 1964

With the instrument described, the dew point of gas flowing in a tube is obtained by observing the temperature at which condensation is formed on a mirror surface that is heated and cooled electrically. Dew points 20 degC below the gas temperature and in the range 50 to -5°C have been measured in gas flows of 40 l. min^{-1}

24,844 A PORTABLE RATEMETER by H.J. Fraser and A.W. Pryor (Austrl. AEC); Proc. IEEE, Austrl., Vol. 25, pp. 96-99, Feb. 1964

A portable transistorized ratemeter is described, which was developed primarily for accurate field measurements with radioactive isotopes. It consumes 0.8 w either from batteries or from a mains-operated power pack, and has a total weight of 10 lb. EHT voltages for polarizing a scintillation counter or Geiger-Müller tube are available in steps of 50 v over the range 300 v to 1450 v. The instrument covers 0-10,000 counts per second in seven linear ranges. The indicated count rate does not deviate by more than ±3 per cent for a battery input of 4.5 v to 7 v or for an ambient temperature of 0°C to 60°C. A window discriminator is provided so that the ratemeter can be used as a single channel pulse height analyzer by varying amplifier gain, or, when searching for an isotope of known energy, a higher signal to background ratio can be obtained. Outputs from the instrument are 3 v positive pulses to drive an external scaler and the ratemeter current (0-1 ma) to drive an external recorder.

24,845 CORRELATION OF I-V CHARACTERISTIC WITH NOISE FOR ION DRIFTED p-i-n JUNCTION PARTICLE DETECTORS by L.K. Monteith (Bell Labs.); Rev. Sci. Instr., Vol. 35, pp. 388-392, Mar. 1964

A technique for achieving minimum noise in a p-i-n particle detector is described. The reverse saturation current of the detector and its relative noise are correlated for different surface treatments. The data show that the reverse current at the detector operating voltage is not a sufficient measure of relative noise. The relative noise can be predicted from the reverse current at two to three times the operating voltage.

24,846 ALPHA RATEMETER WITH SOLID STATE DETECTOR by V. Mandl and L. Oliveira (Joint Nucl. Res. Ctr., Ispra, Italy); Oct. 1963, 11 pp.; STAR, Vol. 2, p. 489(A), Feb. 23, 1964 EUR-429.d, Avail. from Belgian Am. Bank and Trust Co., N.Y., Acct. No. 121.86; 25 Belg. Fr.

A portable alpha monitor with solid state detectors is described. The full scale range is of 1000 PPS and an auditive indication is also provided. The battery life is about 70 hours. The instrument operates correctly in a gamma field up to 8 r/h.

24,847 RESOLUTION STUDY OF SCINTILLATION DETECTORS by D.R. Parsignault (Inst. Nucl. Studies, Saclay) and J.A. Eisele (Texas A and M); Bull. Am. Phys. Soc., Vol. 9, p. 216(A), Mar. 1964

A study of the performance of a 3x3-in. NaI(Tl) scintillation crystal mounted on a DuMont 6363 phototube as a function was carried out. The anode, first dynode, and focusing-grid voltages were independently varied. Sharp dips were observed in the family of resolution versus voltage curves. The variations in resolution show that the most benefit is obtained by focusing carefully. Improvements in resolution over that measured by the manufacturer were as high as 1.5 per cent. A study of the influence that the circuit layout, bleeder resistor, and coupling-capacitor lead length had on resolution was also made. In general, the resolution improved as the lead lengths were shortened and was correlated to an increase in pulse height. However, as the coupling-capacitor lead length was reduced, the pulse height steadily increased, whereas the resolution went through an optimum value and was degraded both for long- and short-lead lengths.

24,848 RADIATION DETECTION BY DECORATION IN SILVER CHLORIDE CRYSTALS by G.B. Childs and L.M. Slifkin (North Carolina U.); 1963, 29 pp., Contract AF49 638 865; U.S. Gov. Res. Rep., Vol. 39, p. 53(A), Apr. 5, 1964 AD 427 405 OTS $2.60

A review is given of the decoration of imperfections in silver halides with emphasis on volume decoration used in radiation detection. The selection, preparation, and decoration of silver chloride crystals are discussed with illustrations of decorated imperfections. Examples of primary cosmic ray particles and high energy proton collisions in silver chloride crystals are presented. The unique features of these crystals as radiation detectors are absence of humidity effects, absence of distortion, nonchemical development at room temperature, delineation of tracks in less than two hours, and crystal thicknesses greater than 3000 microns.

24,849 PERFORMANCE CHARACTERISTICS OF MODULAR NANOSECOND CIRCUITRY EMPLOYING TUNNEL DIODES by N.W. Hill, R.J. Scroggs, and J.M. Madison (Oak Ridge Natl. Lab.); in Neutron Div. Ann. Progr. Rept. Dec. 18, 1963, pp. 127-140, Contract W-7405-eng-26, ORNL-3499, Vol. 2; STAR, Vol. 2, p. 402(A), Feb. 23, 1964 OTS $2.75

Modular circuits employing tunnel diodes have been used in the instrumentation for many of the high-energy particle experiments described. These circuits include discriminator modules, coincidence and anticoincidence modules, positive and negative output scaler-driver modules used to drive commercially built scalers, and a 100 Mc scaler-driver module. Their response to various conditions of temperature and input pulse magnitude was measured.

24,850 A MASS SPECTROMETER DETECTOR USING TWO SEMICONDUCTOR MAGNETIC ELECTRON MULTIPLIERS by N.C. Fenner and R.G. Ridley (Atomic Weapons Res. Estab., Aldermaston); J. Sci. Instr., Vol. 41, pp. 157-159, Mar. 1964

A semiconductor magnetic electron multiplier was constructed and its characteristics were evaluated using a mass spectrometer. A detector using two multipliers with variable separation was also constructed capable of comparing two ion beams simultaneously over a wide mass range. This double detector gave ratios near the statistical limits of accuracy when two isotopes of tungsten were analyzed using an ion beam with intensity varying greatly over short time periods. This electron multiplier has a wide field of application where small size and weight are an important consideration.

24,851 PULSE HEIGHT ANALYZER INCLUDING DIGITAL STORAGE MEANS AND METHOD OF CLASSIFYING AND COUNTING PULSES by R.W. Schumann (Nuclear Data); U.S. Pat. 3,125,721, Issued Mar. 17, 1964

A pulse height analyzer capable of analyzing signal burst in which many pulses may occur is described. Incoming pulses are marked and stored in a memory until analyzed and pulses of particular amplitude are counted and stored only in a corresponding memory address, thereby avoiding the counting of these pulses by a different memory address.

24,852 AUTOMATIC TEMPERATURE CONTROL OF LARGE NUCLEAR REACTORS by W.I. McMillan (GE Ltd.); G.E.C. J. Sci. and Tech., Vol. 31, No. pp. 11-20, 1964

In the present generation of civil reactors of much larger dimensions it is difficult for manual control to be effectively exercised, and for this reason it has been necessary to design automatic control systems which must have a high degree of accuracy and reliability. Methods which improve the reliability of re-

ctor control systems are described. The types of transistor circuits used and me mechanical design are outlined, and the philosophy behind the arrangement f the circuits is discussed.

OTHER APPLICATIONS

4,853 ELECTRONIC DEVICES MAKING STRIDES IN METALWORKING by .B. Ruth (Electronic Ind.); Electronic Ind., Vol. 23, pp. 62-65, Jan. 1964

survey of current electronic devices useful in metalworking is presented. The dvantages and disadvantes of the electron beam, laser, and ultrasonic techiques are presented. Some indication of future developments in this field is iven.

4,854 LASER IRRADIATION OF BIOLOGICAL SYSTEMS by S. Fine and R. cott (Northeastern U.), and E. Klein (Roswell Park Mem. Inst.); IEEE Spectum, Vol. 1, pp. 81-95, Apr. 1964

iological studies on the interaction of laser radiation and biological systems re described. Measurement of electron spin resonance of biological materials radiated at 6943 A indicated with a high probability that free radicals are enerated in the living organism and in isolated biological preparations by exosure to laser radiation. Following irradiation, the inhibition of hemaglutinon by anti-A and anti-B antibodies was increased considerably. Irradiated amma globulin had more precipitative activity with antiserum and less with eumatoid factor than the nonirradiated control specimens. Microscope focsed laser radiation has been used to study effects on cell structure and forms f bacteria. In laser devices the major potential clinical application appears be in the retinal coagulator. Other investigations including laser radiation ffects on tumors, skin and deep seated pathalogical tissues are also discussed.

4,855 SOME CONTRIBUTIONS OF RUBY LASER LIGHT SOURCE TO THE TUDY OF THE PLASMA REFRACTIVITY by U. Ascoli-Baroli (Nat'l. Railroad ab., Rome), S. Martellucci and E. Mazzucato (EURATOM-C.N.E.N., ome); Nuovo Cimento, Vol. 32, p. 298, Apr. 1964

lew possibilities revealed by the use of the ruby laser as a source of light in he study of the refractivity of a plasma in the optical region are examined. The new experimental limits of the optical methods commonly used in the optical diagnostics of ionized gases are discussed and the limits set by the internal structure of the plasma are also examined. New optical methods, made possible by the use of sources of the laser type, are also dealt with including the shadow method that permits the presence of turbulent phenomena in a plasma to be revealed.

24,856 MICROWAVE THEORY AND THE BREAKDOWN OF GASES BY RUBY LASER RADIATION by R. Tomlinson (Ohio State U.); Contract AF 33 657 10824; U.S. Gov. Res. Rep., Vol. 39, p. 129A, Apr. 20, 1964 AD 428 865 OTS$2.60

Microwave breakdown theory is extrapolated to the 6943 Angstroms (ruby laser wavelength). The need for a breakdown criterion other than that for the critical plasma frequency, sometimes used in microwave breakdown, is shown. A suitable criterion is developed from the solution of the electron density continuity equation, including recombination loss. A solution for the breakdown electric field strength, or power density, for the pulsed ruby laser in air as a function of pressure is obtained. The effect of varying pulse duration, initial electron density, and characteristic diffusion length is shown. A minimum power density of 10^{12} watts/sq. cm is predicted for breakdown of air by ruby laser radiation. The extent of accuracy of the results of extrapolating microwave breakdown theory to optical laser breakdown is discussed; and there is speculation on the possibility of additional effects peculiar to laser breakdown.

24,857 SCATTERING OF RUBY LASER LIGHT BY GASES by T.V. George and L. Goldstein, Cont. AF19 604 7473, SR5, 93pp., Oct. 1963; U.S. Gov. Res. Rep., Vol. 39, p. 63A, Apr. 5, 1964 AD 427 730 OTS $9.10

The advent of the laser has made it possible to conduct a more complete study of Rayleigh scattering. Earlier measurements of Rayleigh cross section for gases were made only at right angles to the incident light beam. In the present experiment the angular distribution of the light scattered by gas molecules was measured from 45 to 135 degrees from the direction of the incident beam in argon at one atmosphere and xenon at 135 mmHg of pressure. Experimental results show partial agreement with the Rayleigh theory. The lack of agreement is perhaps due to coherence effects. In argon, the scattered intensity shows a linear pressure dependence. No dependence of scattering cross section on the beam power level was found in either monatomic or polyatomic gases. The differential scattering cross section at an angle of 60 degrees with the beam was determined for various gases and compared with that calculated from known values of refractive indices. An empirical analysis of the discrepancy between the experimental observation and Rayleigh theory is also presented.

SUBJECT INDEX

A

Absorption - See Also Transmission
Absorption,
  Exciton 24,347
  Infrared 24,348
Absorption in:
  AgCl 24,338
  Al Films 24,328
  Alkali Halides, Color Center 24,344
  Alkali Halides:Eu^{2+} 24,337
  Al_2O_3 23,718, 24,342
  CS_2 24,336
  CdS, Double-Photon 24,332
  CdSe 24,333
  GaAs 24,330, 24,421
  GaP 24,401
  Ge:Sn 24,327
  HgCdTe 24,334
  HgTe 24,334
  In Films 24,328
  InAs, Infrared 24,353
  InSb Layers 24,034
  KBr, Irradiation Induced 23,914
  KCl, F-Center 24,345
  KCl:Te 24,345
  KCl:Te, Infrared 24,356
  La Superconductors, Infrared 24,351
  Mica, Infrared 24,352
  MnF_2 24,339
  NaCl:Te, Infrared 24,356
  $NaNO_2$ 24,340
  $NaNO_2$, Infrared 24,354
  PbS 24,431
  PbS, Microwave 24,357
  RbBr:Na, Colloidal 24,346
  RbCl:Na, Colloidal 24,346
  Semiconductors 24,324, 24,343
  Semiconductors, Magnetic Field Effects on 24,326
  Si 24,329
  Si:(B,Li), Infrared 24,350
  ZnS:Mn^{2+} 24,335
Absorption Coefficients, Calculation of 24,325
Absorption Edge in:
  CdS 24,358
  CdTe 24,359, 24,360
  SiC 24,362
  ZnS 24,361
  ZnSb 24,323
Acceptors in ZnTe, Vacancies as 23,970
Acoustic Emission from Al 24,550
Acoustic Wave:
  Absorption in $CuSO_4$ 24,545
  Amplification in Piezoelectrics 24,549
  Damping in Metals 24,538
  Dispersion in Solids 24,543
  Velocity 24,511
  Velocity in:
    Dielectrics 24,546
    Semimetals 24,547
    Semiconductors 24,547
Acoustoelectric Effect, Expressions for 24,071
Acoustoelectric Effect in:
  Ge 24,072
  Si 24,072
Adders, Binary 24,800
Adsorption of O on Diamond 23,572
Alfvén Wave Damping in Bi 24,059
Alkali Halides,
  Absorption in 24,344
  Color Center Production-Destruction in 23,636
  Coloration Rate of 23,639
  Energy Band Structure of 23,841
  Exciton Structure of 23,841
  F-Center Production-Destruction in 23,636
  Hardening in 24,532
  Luminescence of 24,373
  Luminescence Lifetime of F-Centers in 24,402
  M-Center Production-Destruction in 23,636
  Plastic Flow in 24,521
Alkali Halides, (Cont'd)
  Polarization in 23,908
  Positron Annihilation in 23,871
  Spin Resonance of F_2-Centers in 24,265
  Vacancy Annealing in 23,628
Alkali Halides: Eu^{2+},
  Absorption in 24,337
  Fluorescence of 24,337
Alkali Halides: Sm^{2+}, Emission from 24,365
Alloys,
  Piezoresistivity of 23,972
  Resistivity of 23,972
Aluminum,
  Acoustic Emission from 24,550
  Annealing of 23,626
  Dislocation Interactions in 23,680
  Dislocations in 23,656
  Divacancies in 23,626
  Electron Diffraction Streak Patterns in 23,563
  Equation of State for 23,521
  Flow Stress of 24,524
  Oxidation of 23,570
  Stress-Strain Relations in 24,508
  Surface Structure of 23,570
  Thermal Expansion of 24,486, 24,487
  Ultrasonic Attenuation in 24,539
  Vacancies in 23,626
  Vacancy Pits on 23,630
Aluminum Films,
  Absorption in 24,328
  Conductivity of 24,036
  Galvanomagnetic Size Effects in 24,036
  Optical Constants of 24,328
  Refractive Index of 24,328
Aluminum Antimonide, Thermal Expansion of 24,491
Aluminum-Bismuth-Lead, Miscibility Gaps in 23,548
Aluminum-Copper, Growth of 23,790
Aluminum-Magnesium,
  Dislocations in 23,652
  Fatigue Structure of 23,652
Aluminum-Molybdenum, Phase Diagram of 23,541
Aluminum-Nickel-Uranium, Diffusion in 23,732
Aluminum Oxide,
  Absorption in 23,718, 24,342
  Cathodoluminescence of 24,389
  Cr Concentration in 23,718
  Growth of 24,662
  Paramagnetic:
    Relaxation of:
      Fe^{3+} in 24,271
      Ti^{3+} in 24,273
    Resonance:
      Absorption in 24,270
      Lineshapes of Cr in 24,272
      of V^{3+} in 24,285
  Reflection from 24,442
Aluminum Silicate, Paramagnetic Resonance of Cr^{3+} in 24,288
Aluminum-Silver,
  Guinier-Preston Zones in 23,532, 23,533
  Lattice Expansion in 23,625
  Thermal Expansion in 23,625
  Vacancy Concentrations in 23,625
Aluminum Trichloride, Nuclear Quadrupole Coupling in 23,877
Aluminum-Zinc, Precipitation in 23,753
AM Receivers, RF-IF Stages of 24,777
Amblygonite, Thermoluminescence of 24,387
Ammonium Cadmium Sulfate,
  Electro-Optic Effect in 24,453
  Optical Modulation in 24,453
Ammonium Dihydrogen Phosphate, Birefringence of 24,446
Ammonium Hydrogen Sulfate, Specific Heat of 24,472
Ammonium Manganese Fluoride, Specific Heat of 24,473
Ammonium Manganese Sulfate,
  Electro-Optic Effect in 24,453
  Optical Modulation in 24,453
Amorphous Ge, Crystallization by Irradiation of 23,776
Amplifiers,
  Band Pass 24,726
  DC 24,711, 24,712, 24,713
  Differential 24,727
  Direct Coupled 24,712, 24,713
  Electrometer 24,713
  Feedback 24,727
  Feedback Stabilization of 24,710
  High Impedance 24,732
  Integrated 24,727
  K-Band 24,717
  Microwave 24,715
  Noise in 24,723
  Operational 24,713, 24,727, 24,817, 24,818
  Parametric 24,715, 24,716, 24,717, 24,718, 24,719, 24,721, 24,723, 24,724, 24,725
  Power 24,731
  Pulse 24,728, 24,757, 24,765
  Tunnel Diode 24,733
  UHF 24,714
  Video 24,726
  X-Band 24,716
Amplitude Modulators 24,755
Analog Circuits, Design of 24,815
Analog Simulation Techniques 24,816
Analog-to-Digital Converters 24,820
Annealing of:
  Al 23,626
  Defects, Monte Carlo Calculation of 23,618
Anodic Films on Al,
  Electroluminescence of 24,074
  Rectification in 24,074
Anodization of Si 23,810
Antiferroelectric Arrangements in AO_3-Type Crys 23,899
Antiferromagnetic:
  Cr_3S_4 24,096
  Cr_3Se_4 24,096
  Cr_3Te_4 24,096
  Eu:
    Chalcogenides 24,125
    Halogens 24,125
    Silicates 24,125
  $FeNaO_2$ 24,096
  $GeNi_2O_4$ 24,096
  Gd_4Se_3 24,127
Antiferromagnetic Anisotropy of Cr 24,244
Antiferromagnetic Coupling in CdS 24,081
Antiferromagnetic Exchange: 24,091
  Interactions in Semiconductors 24,132
Antiferromagnetic and Ferroelectric Properties in Perovskite-Type Crystals, Coexistence of 24,088
Antiferromagnetic Nuclear Double Resonance in $MnCO_3$ 24,255
Antiferromagnetic Resonance in:
  CoF_2 24,250
  CoO 24,086
  $MnCO_3$ 24,250
  MnO 24,251
  NiF_2 24,250
  NiO 24,251
Antiferromagnetic Resonance Absorption in CoF_2 24,248
Antiferromagnetic Resonance Line Width of MnF_2 24,249
Antiferromagnetic Spin Waves in MnF_2 24,240
Antiferromagnetic State in Eu 24,093
Antiferromagnetic Structure of:
  $CoBr_2$-$6H_2O$ 24,247
  $CoCl_2$-$6H_2O$ 24,247
  $NiBr_2$-$6H_2O$ 24,247
  $NiCl_2$-$6H_2O$ 24,247
Antiferromagnetic Susceptibility of MnHg 24,243
Antiferromagnetic Transitions in Mn-Cu 24,246
Antiferromagnetic-to-Ferromagnetic Transitions 24,102
Antiferromagnetism,
  Band Theory of 24,129, 24,130
  Green's Function Theory of 24,237, 24,239

Antiferromagnets,
  Exchange Interactions in 24,238, 24,242
  Heisenberg 24,234, 24,235
  Low Temperature Behavior of 24,236
  Spin Waves in 24,241
Antimony,
  Energy Band Structure of 24,435
  Phase Transitions in 23,554
  Reflection from 24,435
Antimony in Ge, Diffusion of 23,729, 23,730, 23,733
Antimony Iron Garnets, Ferrimagnetic 24,122
Antiphase Structure of Cu-Au 23,558
Argon (Solid), Energy Band Structure of 23,837
Aromatic Organic Compounds, Emission from 24,364
Arsenic,
  Energy Band Structure of 24,435
  Reflection from 24,435
  Transmission in 24,435
Arsenic in Ge, Diffusion of 23,729
Astable Multivibrators 24,739, 24,740
Atomic Vibrations in:
  TiC 24,493
  TiN 24,493
  ZrC 24,493
  ZrN 24,493
Audio Frequency Modulators 24,756
Austenite, Dislocations in 23,661
Austenite Foils, Phase Transitions in 23,552
Autoclaves 23,772
Avalanche Diodes,
  Characteristics of 24,569
  Noise in 24,571
  Radiation Damage to 24,570
Azulene, Photoconductivity of 24,428

B

Band Pass Amplifiers, Gain Controlled 24,726
Band Pass Filters 24,769
Bardeen-Cooper-Schrieffer:
  Integral Equations on Superconductivity 24,003
  Interactions 24,001
Barium,
  Resistivity of 23,546
  Phase Diagram of 23,546
Barium-Calcium Titanate, Ferroelectric Properties of 23,898
Barium Fluoride, Transmission in 24,355
Barium-Lead Titanate, Ferroelectric Properties of 23,898
Barium-Rare Earth Niobates, Ferroelectric Properties of 23,900
Barium Titanate,
  Breakdown in 23,893
  Crystallization of 23,893
  Dielectric Constant of 23,893
  Dislocations in 23,806
  Domains in 23,912, 23,913
  Electron Diffraction Streak Patterns in 23,563
  Ferroelectricity of 23,806, 23,898
  Growth of 23,805, 23,806
  Lattice Vibrations of 23,864
  Permittivity 23,892
  Reflection from 24,441
  Resistivity of 23,893
Barium Zirconate,
  Breakdown in 23,995
  Dielectric Constants of 23,995
  Resistivity of 23,995
Barium-Zinc Ferrites,
  Crystal Structure of 24,190
  Magnetic Structure of 24,190
bcc Metals, Stacking Faults in 23,691
Beryl, NMR of Be^9 in 24,300
Beryllia, Reflection from 24,442
Beryllium,
  Fermi Surface of 23,846
  Galvanomagnetic Properties of 23,957
  Mossbauer Effect for Fe^{57} in 24,400
Beryllium in BeO, Diffusion (Self) of 23,727
Beryllium^9 in Beryl, NMR of 24,300
Beryllium Chloride,
  Entropy of 23,524
  Heat of Formation of 23,524
Beryllium Oxide,
  Diffusion:
    of O in 23,745
    (Self) of Be in 23,727
  Nuclear Quadrupole Interactions in 23,874
  Reflection from 24,442
Bicrystals,
  Fracture Strength of MgO 24,530
  Orientation of 23,825
Birefringence, Measurement of 24,446
Birefringence of:
  ADP 24,446
  Calcite 24,446
Bismuth,
  Alfvén Wave Damping in 24,059
  Conduction Band of 23,845
  Conductivity of 24,052
  Cyclotron Resonance in 24,059
  de Haas-van Alphen Oscillations in 24,314
  Energy Band Structure of 24,039, 24,435
  Growth of 23,792
  Hall Coefficient of 23,981
  Magnetoacoustic Attenuation in 24,229
  Magnetoresistivity of 24,039, 24,041, 24,042 24,043
  Magnetothermal Oscillations in 24,505
  Reflection from 24,435
  Resistivity of 23,963, 23,981
  Schubnikov-de Haas Effect in 24,039, 24,041
  Transmission in 24,435
Bismuth-Antimony,
  Hall Coefficient of 23,981, 24,045
  Magnetoresistivity of 24,045
  Resistivity of 23,981, 24,045
Bismuth Iron Oxide,
  Electric Ordering in 24,088
  Magnetic Ordering in 24,088
Bismuth Telluride,
  Hall Coefficient of 24,052
  Lattice Parameters of 23,601
  Seebeck Coefficient of 24,052
Bistable Switching Circuits, Cryotron 24,805
Bistable Switching Circuits 24,753
Bloch Equations for Spin Systems 24,137
Bolometers, Thin Film 24,838
Bonded Negative Resistance Diodes, Characteristics of 24,561
Boron,
  Applications of 23,517
  Purification of 23,721
Boron in Si, Diffusion of 23,735
Boron Films, Growth of 23,807
Brass, Vacancies in β- 23,624
Breakdown in:
  $BaTiO_3$ 23,893
  $BaZrO_3$ 23,995
  Transistors, Second 24,580

C

Cadmium,
  Grüneisen Constant of 24,489
  Heat Capacity of 24,463
  Superconducting 24,463
  Thermal Expansion of 24,489
Cadmium in CdS, Diffusion (Self) of 23,737
Cadmium Arsenide, Vaporization of 23,529
Cadmium Iodide,
  Crystal Structure of 23,578
  Growth of 23,578
  Polytype of 23,578
Cadmium Selenide,
  Absorption in 24,333
  Photoconductivity of 24,415
  Photocurrent Pulses in 24,417
  Reflection from 24,436
Cadmium Selenide Films, Resistivity of 23,949
Cadmium Selenide Phosphors, Fluorescence of 24,393
Cadmium Selenide Photoconductive Cells, Recognition Phenomenon in 24,602
Cadmium Sulfide,
  Absorption in 24,332
  Absorption Edge in 24,358
  Antiferromagnetic Coupling in 24,081
  Contacts to 23,289, 23,828
  Crystal Structure of 23,577
  Cyclotron Resonance in 24,058
  Defects in 23,617
  Diffusion (Self) of Cd in 23,737
  Electrical Contacts to 24,070
  Electro-Optic Coefficients of 24,448
  Energy Band Structure 24,437
  Hall Mobility in 23,936
  Junction Formation in 23,577
  Mobility in 23,936
  Phase Transitions in 23,577
  Phonon Scattering in 23,868
  Photoconductivity of 24,064, 24,415
  Photocurrent Saturation in 24,411, 24,412
  Photoemission from 24,064
  Piezoresistance of 23,979
  Recombination Emission from 24,332
  Reflection from 24,437, 24,438
  Resistivity of 23,979
  Schottky Barriers on 24,070
  Surface Properties of 24,070
  Susceptibility of 24,081
  Thermal Conductivity of 23,868
Cadmium Sulfide:I:Cu, Photoconductivity Gain in 24,414
Cadmium Sulfide:Ni^{2+}, Susceptibility of 24,082
Cadmium Sulfide Films,
  Crystal Structure of 23,611
  Photoconductivity of 24,413
Cadmium Sulfide Photoconductive Cells, Recognition Phenomenon in 24,602
Cadmium Sulfo-Selenide, Photo Ionization in 24,416
Cadmium Telluride,
  Absorption Edge in 24,359, 24,360
  Cyclotron Resonance in 24,060
  Crystal Structure of 23,577
  Energy Band Structure of 24,359
  Junction Formation in 23,577
  Phase Transitions in 23,577
  Phonon Scattering in 23,868
  Refractive Index of 24,445
  Thermal Conductivity of 23,868
Cadmium Telluride in:
  PbTe, Solubility of 23,535
  SnTe, Solubility of 23,535
Cadmium Telluride Films,
  Hall Mobility of 23,950
  Resistivity of 23,950
Calcite,
  Birefringence of 24,446
  Dislocation-Twin Interactions in 23,683
  Paramagnetic Resonance Absorption of Fe^{3+} in 24,280
  Twinning in 23,683
Calcium,
  Cyclotron Mass of 23,852
  de Haas - van Alphen Effect in 23,852
  Fermi Surface of 23,852
Calcium Fluoride, Paramagnetic:
  Relaxation of Gd^{3+} in 24,278
  Resonance of:
    Fe^{3+} in 24,293
    Gd^{3+} in 24,298
Calcium Fluoride:Dy^{2+} Lasers, Sun-Pumped 24,648
Calcium Oxide, Paramagnetic Resonance of Fe^{2+} in 24,294
Calcium Oxide-Silicon Dioxide-Chromium Oxide, Miscibility Gap in 23,547
Calcium Tungstate, Paramagnetic Resonance of:
  Cr^{4+} in 24,289
  Nd^{3+} in 24,297

Calcium Tungstate:Nd Lasers, Pumping in 24,649
Calcium-Yttrium-Zirconium Oxide,
  Conductivity of 23,989
  Order-Disorder Transitions in 23,989
  Phase Transitions in 23,989
Carbon in:
  Co, Diffusion of 23,747
  Fe, Diffusion of 23,747
  Fe-Co, Diffusion of 23,747
  Ni, Solubility of 23,534
Carbon Arc Furnaces 23,770
Carbon Sulfide, Absorption in 24,336
Carrier Concentration in:
  In $As_y Sb_{1-y}$ Films 24,331
  SnTe 23,833
  ZnSb 24,323
Carrier Density in:
  Ge 24,057
  InSb, Grain Boundary 23,980
  TiC_xN_{1-x} 24,055
  $TiV_{1-x}C$ 24,055
Carrier Systems for Telephony 24,785
Carriers in GeTe 23,917
Casting of InSb 23,779
Catalysis by Ag, Dislocation Effects on 23,817
Cathodoluminescence of:
  Al_2O_3 24,389
  $MgAl_2O_4$ 24,388
Ceramics,
  Domains in Ferroelectric 23,911
  Polarization of Ferroelectric 23,910
Cerium,
  Electronic Structure of 23,849
  Fermi Surface of 23,849
  Melting of 23,719
  Phase Diagram of 23,545
  Purity Analysis of 23,719
  Thermal Expansion Coefficient of 24,488
Cerium-Gadolinium Ruthenium,
  Ferromagnetic 24,124
  Superconductive 24,124
Cesium,
  Fermi Surfaces of 23,870
  Heat Capacity of 24,460
  Specific Heat of 24,462
Cesium Bromide,
  Compressibility of 24,474
  Elastic Constants of 24,517
  Grüneisen Constant of 24,474
  Specific Heat of 24,474
  Thermal Expansion of 24,474
Cesium Iodide, Elastic Constants of 24,517
Cesium Manganese Fluoride, Specific Heat of 24,473
Charge on Dislocations in AgCl 23,667
Chemical Equilibria in:
  Ge-Br 23,787
  Ge-I 23,787
  GeI_2 23,722
Chemisorption 23,813
Chlorides, Phase Diagrams of the 23,538
Chlorine Interstitials in NaCl, Energies of 23,633
Choppers,
  Field Effect Transistor 24,772
  Temperature Effects in 24,771
Chromic Bromide,
  Magnetization of 24,142
  Spin-Waves in 24,142
Chromic Selenide,
  Antiferromagnetic 24,096
  Magnetic Structure of 24,096
Chromic Sulfide,
  Antiferromagnetic 24,096
  Magnetic Structure of 24,096
Chromic Telluride,
  Antiferromagnetic 24,096
  Magnetic Structure of 24,096
Chromite Spinels, Thermal Conductivity of 24,483
Chromium, Antiferromagnetic Anisotropy of 24,244
Chromium in:
  Al_2O_3, Paramagnetic Resonance Lineshapes of 24,272
Chromium in: (Cont'd)
  Diffusion of 23,748
Chromium^{+} in:
  ZnSe, Paramagnetic Resonance of 24,290
  ZnTe, Paramgnetic Resonance of 24,290
Chromium^{3+} in Al_2SiO_5, Paramagnetic Resonance of 24,288
Chromium^{4+} in $CaWO_4$, Paramagnetic Resonance of 24,289
Chromium Concentration in Al_2O_3 23,718
Chromium-Acetic Acid Salts, Susceptibility of 24,084
Chromium Disilicide,
  Effective Mass of 23,993
  Energy Gap of 23,993
  Hall Coefficient of 23,993
  Mobility Ratio of 23,993
  Resistivity of 23,993
  Thermoelectric Power of 23,993
Chromium Iodide,
  Magnetoresistivity of 24,083
  Resistivity of 24,083
  Susceptibility of 24,083
Chromium Oxide, Growth of 23,800
Chromium Trichloride,
  Covalency Parameters of 23,579
  Crystal Structure of 23,579
  Nuclear Quadrupole Measurement of 23,579
  Phase Transformation in 23,579
Cleavage Cracks in Fe-Si 23,714
Cobalt,
  Creep in 24,526
  Diffusion of C in 23,747
  Ferromagnetic Resonance Linewidth in 24,216
  Magnetization of 24,150
  Nernst-Ettingshausen Effect in 24,502
  Stacking Faults in 23,703
Cobalt Films,
  Crystal Structure of 23,609
  Magnetic:
    Domain Structures in 24,191
    Hysteresis in 24,189
  Spin-Waves in 24,144
Cobalt Whiskers, Growth of 23,795
Cobalt Ferrite,
  Mössbauer Effect in 24,261
  Superparamagnetism in 24,261
Cobalt Ferrite Films, Growth of 23,798
Cobalt-Manganese-Silicon, Crystal Structure of 23,600
Cobalt Manganite, Free Energy of Formation of 23,526
Cobalt-Nickel,
  Resistivity of 23,695
  Stacking Faults in 23,695
Cobalt-Nickel-Phosphorous Films, Magnetization Reversal in 24,176
Cobalt Oxide,
  Antiferromagnetic Resonance in 24,086
  Growth of 23,797, 23,800
  Reflection from 24,440
  Susceptibility of 24,086
Cobalt Oxide-Manganese Oxide, Solutions of 23,526
Cobalt Sulfide,
  Lattice Parameters of 23,606
  Thermal Expansion of 23,606
Cobalt Titanate,
  Crystal Structure of 23,591
  Susceptibility of 23,591
Cobaltous Bromide, Proton Resonance in 24,247
Cobaltous Chloride,
  Magnetic Transitions in 24,103
  Proton Magnetic Resonance in 24,103
  Proton Resonance in 24,247
Cobaltous Fluoride,
  Antiferromagnetic:
    Resonance in 24,250
    Resonance Absorption in 24,248
  Transmission in 24,250
Code Generators 24,083
Coincidence Circuits Tunnel Diode 24,849
Colloidal Absorption in:
  RbBr:Na 24,346
  RbCl:Na 24,346
Color Center Absorption in Alkali Halides 24,344
Color Center Luminescence of Alkali Halides, Lifetime of 24,402
Color Centers, Raman Effect in 24,363
Color Centers in:
  Alkali Halides,
    Production-Destruction by X-Rays of 23,636
    Spin Resonance of 24,265
  KBr,
    Generation by Electrons and X-Rays of 23,63
    X-Ray Induced 23,642
  KCl 23,646
  KCl,
    Absorption of 24,345
    Annealing of 23,645
    Defect Effects on 23,643
    Generation by Electrons and X-Rays of 23,63
    Growth of 23,645
    Impurity Effects on 23,644
  KI, Formation of 23,641
  LiF, Generation by Electrons and X-Rays of 23,637
  NaCl,
    Defect Effects on 23,640
    Generation by Electrons and X-Rays of 23,63
    Luminescence of 24,403
  NaN_3,
    Bleaching of 23,638
    Formation of 23,638
  Quartz, Paramagnetic Resonance of 24,266
Coloration Rate of Alkali Halides 23,639
Communication Systems,
  Laser 24,789
  Maser 24,788
Compressibility of:
  CsBr 24,474
  KBr 24,474
  KCl 24,474
  NaCl 24,474
Compressibility-Defect Relationships 23,623
Compression of:
  Eu 24,527
  Pr 24,527
  Sc 24,527
  Tb 24,527
  Yb 24,527
Computer Circuitry, Laser 24,822
Conduction in:
  Ge, Impurity 23,953
  Metal Oxides, Vacancy Effects on 23,982
  Semiconductors, Impurity 23,952
Conduction Band of Bi 23,845
Conductivity - See Also Resistivity
Conductivity, Microwave Measurement of 23,954
Conductivity of:
  Al Films 24,036
  $AuSb_2$ 23,994
  Bi_2Te_3 24,052
  $CaO-Y_2O_3-ZrO_2$ 23,989
  Cu_2Sb 23,994
  GaAs, Oscillations in 23,998
  Ge, Temperature Dependence of 23,965
  InP, Oscillations in 23,998
  InS_3 23,834
  InSb, Grain Boundary 23,980
  K, Pressure Effects on 23,973
  KCl, Ionic 23,990
  Li, Pressure Effects on 23,973
  Na, Pressure Effects on 23,973
  NiO(Li) 23,941
  Organic Semiconductors 23,938
  Semiconductors, Theory of 23,951
  Si, Microwave 23,956
  SiO Films 23,887
  $SrTiO_3$ 23,992
  TiO_2, Aging Dependence of 23,986
  UO_2 23,987

Conductivity of: (Cont'd)
ZnSb 23,939
Zn_3Sb_2 24,075
ZnTe, High Temperature 23,970
ZrO-CaO 23,988
Contacts to:
CdS, Preparation and Properties of 23,828, 23,829
Si, Sparked 24,600
Controlled Rectifiers,
Applications of 24,701
Bilateral 24,701
Controls,
Lighting 24,834, 24,835
Motor 24,829, 24,830, 24,831, 24,832
Reactor 24,852
Temperature 24,852
Shutter 24,836
Converters,
Analog-to-Digital 24,820
Frequency 24,762
Gray Code 24,821
Impedance 24,767, 24,768
Parametric 24,762
Tunnel Diode 24,758
Copper,
Defects in 23,616
Diffusion (Surface) of Ge on 23,731
Dislocation:
Distribution in 23,684
Peaks in 24,551
Dislocations in 23,651
Energy Band Structure of 23,836
Equation of State for 23,521
Growth of 23,790
Gruneisen Constant of 24,490
Heat Capacity of 24,463
Internal Friction in 24,551
Lattice Parameters of 23,603
Mössbauer Effect for Fe^{57} in 24,400
Rolling Texture of 23,689
Slip in 23,716
Slip Lines in 23,684
Stacking Faults in 23,689
Strain Hardening in 24,533
Superconducting 24,463
Surface Structure of 23,568
Thermal:
Conductivity of 24,479
Expansion of 24,486, 24,490
Thermoelectric Power of 24,498
Vacancy Annealing in 23,627
Young's Modulus of 24,516
Copper (Impure),
Magnetic Properties of 24,123
Specific Heat of 24,123
$Copper^{2+}$ in $Zn_2P_2O_7$, Paramagnetic Resonance of 24,284
Copper Films,
Photoemission from 24,063
Secondary Electron Emission from 24,063
Stacking Faults in 23,692
Twins in 23,692
Copper Solid Solutions, Stacking Faults in 23,693
Copper Whiskers, Resistivity of 23,694
Copper-Aluminum, Stacking Faults in 23,696, 23,697
Copper Antimonide,
Conductivity of 23,994
Hall Coefficients of 23,994
Thermoelectric Power of 23,994
Copper-Cobalt,
Magnetic Properties of 24,123
Specific Heat of 24,123
Copper-Germanium, Stacking Fault Energy of 23,698
Copper-Gold, Antiphase Structure of 23,558
Copper Gold (Cu_3Au),
Ordering in 23,556
Vacancy Formation in 23,556
Copper-Iron,
Magnetic Properties of 24,123
Specific Heat of 24,123
Copper Iron Sulfide (Cu_5FeS_4),
Crystal Structure of 23,582
Polymorphs of 23,582
Copper-Nickel,
Resistivity of 23,695
Stacking:
Fault Energy of 23,694
Faults in 23,695, 23,696, 23,697
Copper Potassium Sulfate, Paramagnetic Resonance in 24,264
Copper-Silicon, Etching of 23,818
Copper-Silicon-Zinc, Lattice Parameters of 23,604
Copper Sulfate,
Acoustic Wave Absorption in 24,545
Ultrasonic Wave Absorption in 24,545
Copper Sulfide,
Crystal Structure of 23,581
Preparation of 23,581
Copper-Zirconium, Phase Diagram of 23,543
Corbino Disks, Magnetoresistivity of InSb 24,047
Corundum,
Growth of 23,800
Paramagnetic:
Relaxation of:
Fe^{3+} in 24,271
Ti^{3+} in 24,273
Resonance of V^{3+} in 24,285
Counters,
Decade 24,796
Integrated 24,798
Pulse 24,764
Ring 24,799
Tunnel Diode 24,797
Covalency Parameters of $CrCl_3$ 23,579
Cracks in:
MgO 24,530
Zn-Hg, Initiation of 23,713
Creep in:
Co 24,526
P (White), Pressure Dependence of 24,525
Critical Current of Superconductors (II) 24,018
Critical Field of:
In-Pb Superconductors 24,019
Pb-Tl Superconductors 24,020
Critical Temperature of:
Nb Superconducting Films 24,011
Ta Superconducting Films 24,011
V Superconducting Films 24,011
Cryotron Shift Registers 24,805
Cryotron Switching Circuits 24,805
Crystal Filters 24,770
Crystal Interfaces, Energy States at 23,855
Crystal Orientation,
Goniometer Measurement of 23,823
Laue Method of 23,825
Measurement of 23,824
Crystal Oscillators 24,734
Crystal Structure - See also Surface Structure; Lattice Parameters
Crystal Structure,
Computer:
Analysis of 23,559
Programs for 23,560
Diffractometers for Measuring 23,562
Electron Diffraction Streak Patterns in 23,563
Proton Magnetic Resonance in 23,565
X-Ray Reflection in 23,566
Crystal Structure of:
$AgFeO_2$ 23,596
Au_3Mn 23,605
Ba-Zn Ferrites 24,190
α-$C_{10}H_7HgI$ 23,576
CdI 23,578
CdS 23,577
CdS Films 23,611
CdTe 23,577
Co Films 23,609
Co-Mn-Si 23,600
Crystal Structure of: (Cont'd)
$CoTiO_3$ 23,591
$CrCl_3$ 23,579
Cu_5FeS_4 23,582
$CuS_{1.96}$ 23,581
Diamond 23,574
Fe 23,564
$Fe_{1.1}Cr_{0.9}B_{0.9}$ 23,599
Fe-Mn-Si 23,600
Fe_2MoC 23,598
$FeNbO_4$ 23,597
GaAs Films, Electron Diffraction Study of 23,610
Ga-Nb Oxides 23,886
GaP 23,577
Group:
I-VIII Compounds 23,577
II-VI Compounds 23,577
III-V Compounds 23,577
H_2S (Solid) 23,580
HfSn 23,586
InTe 23,575
$MgSO_3 \cdot 3H_2O$ 23,593
Nb:
Carbides 23,590
Oxide Films 23,612
$Nb_2O_5 \cdot 3WO_3$ 23,594
Nb-Re 23,589
Pt-Al Films 23,613
Rare Earth-Be (RBe_{13}) 23,584
$ScCd_3$ 23,587
Si 23,573
$SrZn_2$ 23,583
Ta-Nb Oxide 23,595
ThPd 23,588
(Ti-Re)Si 23,585
$UMoC_2$ 23,592
ZnS 23,577
Crystallization,
Kinetics of 23,758
Segregation in Spherulitic 23,760, 23,761
Crystallization of:
$BaTiO_3$ 23,893
Ge, Irradiation 23,776
Polymers 23,760, 23,761
Cupron, Magnetization of 24,160
Cuprous Oxide,
Dislocations in 23,662
Electroluminescence of 24,381
Photoconductivity of 24,425
Cuprous Selenide-Zinc Selenide Heterojunctions, Electroluminescence of 24,372
Cuprous Sulfide-Zinc Sulfide Heterojunctions, Electroluminescence of 24,372
Curie Temperature of:
Gd, Pressure Effect on 24,166
Rare Earth Orthoferrites 24,168
YIG (Ion Substituted) 24,167
Curium, Fluorescence of 24,392
Current Crowding in Transistors 24,581
Current Instabilities in:
Semiconductors 23,997
Semimetals 23,997
Current Supplies,
DC Magnet 24,826
Laser 24,678
Current Supplies 24,825
Current-Voltage Relation in Space Charge of Diodes 24,560
Cyclotron Mass of:
Ca 23,852
PbS 24,040
Cyclotron Resonance in:
Bi 24,059
CdS 24,058
CdTe 24,060
Ge 24,057
Cyclotron Resonance of Hot Electrons 24,056

D

Data Transmission System for Telephony 24,786
DC Amplifiers 24,711, 24,712, 24,713
DC Current Supplies, Magnet for 24,826
DC Power Supplies 24,827
DCTL Logic Circuits 24,794
Debye Temperature - See Also Specific Heat
Debye Temperature of:
  Nb 24,030
  TiC 24,493
  TiN 24,493
  ZrC 24,493
  ZrN 24,493
Decade Counters 24,796
Decoration of:
  Ag, Facet 23,821
  AgCl, Dislocation 24,557
  Ge 23,820
  Si 23,820
Defect Concentration in GaAs, Irradiation Effects on 24,480
Defect-Compressibility Relationships 23,623
Defect-Thermal Expansion Relationships 23,623
Defects,
  Annealing of 23,618
  Electronic Properties of 23,622
  Interaction of 23,621
  Irradiation Dependence of 23,616
Defects in:
  Ag Halides, X-Ray Diffraction Study of 23,614
  CdS, Radiation 23,617
  Cu, Irradiation Dependence of 23,616
  Graphite 23,620
  KBr, Irradiation Induced 23,914
  Rh, Annealing of 23,984
  Si,
    Heat Treat Effects on 23,663
    Neutron Irradiation Induced 23,615
  W, Irradiation Induced 23,619
de Haas-van Alphen Effect in:
  Bi 24,314
  Ca 23,852
  Ga 24,316, 24,317
  Re 24,315
  Tl 24,319
  Zn 24,318
Demodulators, Optical 24,610
Density of $(Ag_2Te)_{0.41}$-$(Sb_2Te_3)_{0.59}$ 23,781
Desorption from Metals 23,814
Desorption of:
  F from Mo 23,816
  K from W 23,815
Detectors,
  Particle 24,845
  Pulse 24,640
  Radiation 24,839, 24,846, 24,848
  Tunnel Diode 24,759
Dew Point Meters 24,843
Diamagnetic Susceptibility, Measurement of 24,076
Diamagnetic Susceptibility of:
  Diamond 24,258
  Ge 24,258
  Si 24,258
  SmallSystems, Size Corrections to 24,313
  Sn 24,258
Diamond,
  Adsorption of O_2 on 23,572
  Crystal Structure of Irradiated 23,574
  Dielectric Constant of 23,889, 24,322
  Elastic Constants of 23,889
  Interstitials in 23,631
  Optical Transitions in 24,322
  Paramagnetic Resonance Study of 23,574
  Preparation of 23,772
  Radiation from 24,366
  Reflection from 24,322
  Surface Structure of 23,572
  Susceptibility of 24,258
  Trigons on Twin Boundaries in 23,708
  Twin Boundaries in 23,708
  Vacancies in 23,631
Dielectric - See Also Ferroelectric
Dielectric Constant - See Also Permittivity
Dielectric Constant,
  Measurement of 23,884, 23,955
  Theory of 23,880
Dielectric Constant of:
  $BaTiO_3$ 23,893
  $BaZrO_3$ 23,995
  Diamond 24,322
  Diamond, Pressure Variation of 23,889
  InS_3 23,834
  $NaNO_2$ 23,890
  PbTe 23,888
  Rutile, Electric Field Variation of 23,891
  S Powders 23,894
Dielectric Constants,
  Measurement of 23,882
  Tables of 23,879
Dielectric Dispersion in Rochelle Salt 23,895
Dielectric Loss, Measurement of 23,884
Dielectric Loss of $NaNO_2$ 23,890
Dielectric Loss Tangent, Measurement of 23,883
Dielectric Properties of:
  Ga-Nb Oxides 23,886
  SiO Films 23,887
Dielectric Relaxation in KBr, Irradiation Induced 23,914
Dielectrics,
  Acoustic Wave Velocity in 24,546
  Second Sound Velocity in 24,546
  Ultrasonic:
    Wave Velocity in 24,546
    Waves in 24,535
Differential Amplifiers 24,727
Diffractometers 23,562
Diffusion,
  Lapping Device for Measuring 23,727
  Theory of 23,724
Diffusion in:
  Al-Ni-U 23,732
  BeO,
    Be Self- 23,727
    O 23,745
  CdS, Cd Self- 23,737
  Co, C 23,747
  Epitaxial Layers 23,728
  Fe, C 23,747
  Fe-Co, C 23,747
  GaAs 23,738
  GaAs,
    Ag 23,744
    S 23,743
    Se 23,743
    Te 23,743
    Zn 23,739, 23,740, 23,741, 23,742
  GaP, Zn 23,740
  Ge,
    As 23,729
    Ga 23,729
    In 23,729
    Sb 23,729, 23,730, 23,733
    Ta 23,734
  Glass, Fe 23,750
  MgO,
    Fe 23,749
    Ni Grain Boundary 23,746
  Ni, Cr 23,748
  Si,
    B 23,735
    P 23,736
Diffusion of:
  Ag in GaAs 23,744
  As in Ge, Dislocation Effects on 23,729
  B in Si 23,735
  Be in BeO, Self- 23,727
  C in:
    Co 23,747
    Fe 23,747
    Fe-Co 23,747
  Cd in CdS, Self- 23,737
  Cr in Ni 23,748
Diffusion of:
  Fe in:
    Glass 23,750
    MgO 23,749
  Ga in Ge, Dislocation Effects on 23,729
  In in Ge, Dislocation Effects on 23,729
  Ni in MgO, Grain Boundary 23,746
  O in BeO 23,745
  P in Si, P Nitride as Source for 23,736
  S in GaAs 23,743
  Sb in:
    Ge 23,733
    Ge,
      Dislocation Effects on 23,729
      Electric Field Effects on 23,730
  Se in GaAs 23,743
  Ta in Ge 23,734
  Te in GaAs 23,743
  Zn in:
    GaAs 23,739, 23,740, 23,741, 23,742
    GaP 23,740
Diffusion (Surface) of Ge on Cu 23,731
Diffusion Coefficients, Determination of 23,726
Diffusion Equation, Solution of 23,725
Diffusion-Induced Dislocation Networks in Si 23,665
Diodes - See Also Rectifiers
Diodes,
  Avalanche 24,569, 24,570, 24,571
  Bonded Negative Resistance 24,561
  Capacitance Variation in 24,698
  Four Layer 24,573
  GaAs Laser 24,620, 24,621, 24,622, 24,623, 24,624, 24,626, 23,739
  $Ga(As_{1-x}P_x)$ Laser 24,625
  Gate Turn-Off 24,574
  InAs Laser 24,628
  InP Laser 24,626, 24,627
  InSb Laser 24,629
  Laser Heterodyning by 24,650
  Logic 24,575
  Luminescence of:
    GaAs 24,368
    GaP 24,369
  Microminiature 24,575
  Negative Resistance of Tunnel 24,565
  Noise in 24,571
  Planar 24,560
  Radiation from GaP 24,370
  Reverse Current of Diodes, Measurement of 24,558
  SiC Laser 24,630
  Surface Barrier 24,563
  Switching:
    Characteristics of Four Layer 24,573
    Time of Tunnel 24,566
    Times of Narrow Base 24,559
  Tunnel - See Tunnel Diodes
  Varactor 24,572, 24,698, 24,702
  Voltage-Elastance of 24,572
Direct Coupled Amplifiers 24,712, 24,713
Discriminators,
  Pulse 24,765
  Pulse Height 24,766
  Tunnel Diode 24,849
Dislocation Configurations in Nb Foils 23,711
Dislocation Dipoles 23,678
Dislocation Loops,
  Elastic Energy of 23,676
  Electron Microscope Measurement of 23,653
Dislocation Networks in Si, Diffusion-Induced 23,665
Dislocation Nucleation 23,650
Dislocation Peaks in:
  Ag 24,551
  Au 24,551
  Cu 24,551
  Pt 24,551
Dislocation Relaxation in:
  Nb 24,555
  Ta 24,555

Dislocation Velocity, Stress Dependence of 23,674
Dislocation Width, Peierls Force Dependence of 23,668
Dislocation-Twin Interactions in:
  Calcite 23,683
  Zn 23,683
Dislocation-Vacancy Interactions 23,681
Dislocations,
  Calculations on 23,648
  Dilation Field of 23,679
  Edge 23,675
  Elastic:
    Field of Edge 23,675
    Properties of 23,677
  Electron Microscope Measurement of 23,651
  Kinetic Theory of 23,647
  Motion of 23,669
  Scattering of Excitons by 23,947
  Screw 23,679
  Statistics of 23,640
Dislocations in:
  Ag 24,551
  AgCl,
    Charge on 23,667
    Decoration of 24,557
  Al 23,656, 24,524
  Al, Interactions of 23,680
  Al-Mg 23,652
  Au 24,551
  Austenite 23,661
  $BaTiO_3$ 23,806
  Calcite 23,683
  Cu 23,651, 24,551
  Cu, Distribution of 23,684
  Cu_2O 23,662
  fcc Metals, Mobility of 23,670
  Fe 23,657, 24,531
  Ferrite 23,661
  Ge 23,685, 24,522
  LiF,
    Jumps in 23,671, 23,672
    Motion of 23,673
  LiH_3SeO_2, Etching of 23,654
  NaCl 23,659
  NaCl,
    Boundaries of 23,666
    Distribution of 23,686
    Etching of 23,655
    X-Ray Induced 23,664
  Nb: 24,555
    Foils 23,711
  PbS 23,660
  Polymer Crystals 23,658
  Pt 23,651, 24,551
  Si 23,665, 23,699, 23,700
  SnS_2 23,705
  Ta 24,555
  Ta, Interaction Between Interstitials and 23,682
  W, Interaction Between Interstitials and 23,682
  Zn 23,683
  $ZnWO_3$ 23,802
Dislocations on Yielding in Fe, Effect of 24,531
Display Systems, Laser 24,822
Distribution of Pb in Ag-Sb-Te 23,536
Distribution Coefficient of Zn in:
  GaAs 23,740
  GaP 23,740
Divacancies in Al 23,626
Dividers, Frequency 24,736
Domain Structure in:
  Ni-Fe Films, Magnetic 24,192
  Co Films, Magnetic 24,191
Domain Wall Creep in:
  Films, Magnetic 24,195
  Ni-Fe Films, Magnetic 24,196
Domain Wall Motion, Magnetic 24,193
Domain Wall Motion in Magnetic Films 24,194
Domain Walls in:
  Ferromagnets, Defect Effects on 24,151
  Films, Magnetic 24,197, 24,198
Domains in:
  $BaTiO_3$ 23,912, 23,913
  Ferroelectric Ceramics 23,911
Donors in Ge, Paramagnetic Resonance of 24,267
Doping of Si Films 23,723
Double-Base Diodes, Applications of 24,703
Dysprosium,
  Magnetization of 24,087
  Magnetostriction of 24,107
Dysprosium Aluminum Garnet, Magnetic Transitions in 24,101
Dysprosium Ethyl Sulfate, Paramagnetic Resonance of Gd in 24,299
Dysprosium Palladium ($Dy_{5.07}Pd_{1.93}$), Ferromagnetic 24,126

E

Edge Dislocations, Elastic Field of 23,675
Effective Charge of Ions 23,933
Effective Mass in:
  $CrSi_2$ 23,993
  Ga 24,317
  GaAs, Electron 23,932
  Ge, Electron 23,932
  Graphite 23,847
  HgTe 24,334
  InAs, Electron 23,931, 23,932
  InSb, Electron 23,932
  Pb 23,853
  PbS 23,838
  Si, Electron 23,932
  ZnSb 24,323
Effective Mass versus Orientation for Ga 24,317
Effective Mass Ratio of:
  Cs 24,462
  In As_y Sb_{1-y} Films 24,331
Elastic Constants,
  Calculation of 24,514
  Higher Order 24,510, 24,511
  Temperature Dependence of 24,513
  Third Order 24,511
Elastic Constants of:
  Anisotropic Solids, Third Order 24,512
  CsBr, Temperature Variation of 24,517
  CsI, Temperature Variation of 24,517
  Diamond 23,889
  K 24,459
  K, Pressure Dependence of 24,515
  Ni-Cu 24,518
  Ni-Fe 24,518
  Pyroxenes 24,519
Elastic Waves in Ge, Attenuation of 24,507
Elasticity, Theory of 24,059
Electric Ordering in:
  $BiFeO_3$ 24,088
  $YMnO_3$ 24,088
  $YbMnO_3$ 24,088
Electrical Contacts to CdS 24,070
Electro-Optic Coefficients of CdS 24,448
Electro-Optic Effect in:
  $(NH_4)_2Cd_2(SO_4)_3$ 24,453
  $(NH_4)_2Mn_2(SO_4)_3$ 24,453
  Crystals 24,447
Electro-Optic Modulators for Lasers 24,677
Electroluminescence, Voltage Dependence of 24,374
Electroluminescence of:
  Anodic Films on Al 24,074
  Cu_2O, Infrared 24,381
  Cu_2S-ZnS Heterojunctions, Injection 24,372
  Cu_2Se-ZnSe Heterojunctions, Injection 24,372
  Oxide Phosphors 24,382
  Zn-Cd-S-Se Phosphors-Luminors 24,375
  ZnO Phosphors, Voltage Dependence of 24,374
  ZnS Phosphors, Voltage Dependence of 24,374
  ZnS:Cu: 24,378
    Phosphors, Voltage Variation Effects on 24,377
  ZnS:Cu:Al Phosphor 24,379
Electroluminescence of: (Cont'd)
  ZnS:Cu: Halogen Phosphors, Deterioration in 24,380
  Zn(S:Se):Cu Phosphors, Variations in 24,376
Electrolytic Growth, Double Cell for 23,771
Electrometer Amplifiers 24,713
Electron Diffraction Streak Patterns 23,563
Electron Effective Mass of:
  GaAs, Temperature Dependence of 23,932
  Ge, Temperature Dependence of 23,932
  InAs, Temperature Dependence of 23,931, 23,932
  InSb, Temperature Dependence of 23,932
  Si, Temperature Dependence of 23,932
Electron Emission from:
  Au Films, Secondary 24,063
  Cu Films, Secondary 24,063
  Ge Films, Secondary 24,063
  KBr Films, Secondary 24,062
  KCl, Secondary 24,061
Electron Mobility of:
  Nb_2O_5, High Temperature 23,943
  TiO_2, High Temperature 23,943
Electron Multipliers 24,850
Electron Recombination in Ge 23,925, 23,929
Electron Scattering, Relaxation in 23,946
Electron Scattering in:
  Ge, Anisotropic 23,945
  Si, Anisotropic 23,945
Electron Spin Oscillators 24,748
Electron Temperature, Electric Field Effects on 23,918
Electron Tunneling from Excited F-Centers 24,073
Electronic Structure of:
  Ce 23,849
  Ge 23,872
  Gd 23,849
  Metals 23,870
  Na 23,850
  Sn 23,872
  Yb 23,849
Electrostriction in TGS 23,916
Emission from:
  Alkali Halides:Sm^{2+}, Polarized 24,365
  Aromatic Organic Compounds, Stimulated 24,364
  Au Films, Electron 24,063
  Cu Films, Electron 24,063
  Gd_2O_3:Nd^{3+}, Stimulated 24,396
  Ge Films,
    Electron 24,063
    Field 24,065
  KBr Films, Electron 24,062
  KCl, Electron 24,061
  Ta, Ion 24,066
Energy Band Structure of:
  A(Solid) 23,837
  Al 24,328
  Alkali Halides 23,841
  As 24,435
  Au-Si 24,069
  Bi 24,039, 24,435
  CdS 24,437
  CdTe 24,359
  Cu, APW Calculation of 23,836
  GaAs 23,844
  GaSb 23,977
  GeTe 24,435
  Group:
    IV-VI Compounds 24,435
    V Semimetals 24,435
  Inert Gases (Solid) 23,841
  Ni 23,839
  Pb-Group VI Compounds 24,435
  PbS 23,838, 24,040, 24,435
  PbSe 24,435
  PbTe 24,435
  Sb 24,435
  SnTe 23,833, 24,435
  $SrTiO_3$ 23,992
  TiC_xN_{1-x} 24,055
  $TiV_{1-x}C$ 24,055

Energy Gap of:
A (Solid) 23,837
$CrSi_2$ 23,993
GaP 24,422
InSb 24,053
Nb Superconductors 24,030
PbS 23,838
Superconducting Films 24,015
ZnS 23,842
Zn_3Sb_2 24,075
Energy Gap Transitions in Semiconductors 23,843
Energy Levels in Si 23,974
Energy States at Crystal Interfaces 23,855
Entropy of BeCl 23,524
Epitaxial Growth, Bibliography on 23,764
Epitaxial Growth of Semiconductor Films, Bibliography on 23,764
Epitaxial Layers, Diffusion in 23,728
Equations of State, Formulation of 23,520
Equations of State for:
Ag 23,521
Al 23,521
Cu 23,521
fcc Metals 23,521
Erbium, Magnetization of 24,087
Etchants for Na and K 23,789
Etching of:
Ag, Facet 23,821
CuSi, Thermal 23,818
Ge, Vapor 23,819
LiH_3SeO_2, Dislocation 23,654
NaCl, Dislocation 23,655
$ZnWO_3$, Dislocation 23,802
Europium,
Compression of 24,527
Magnetic Properties of 24,093
Europium Chalcogenides,
Antiferromagnetic 24,125
Ferromagnetic 24,125
Europium Gadolinium Selenide ($Eu_{0.5}Gd_{1.6}Se_{2.9}$), Paramagnetic 24,127
Europium Halogens,
Antiferromagnetic 24,125
Ferromagnetic 24,125
Europium Oxide,
Preparation of 24,469
Specific Heat of 24,469
Susceptibility of 24,257
Europium Silicates,
Antiferromagnetic 24,125
Ferromagnetic 24,125
Europium Sulfide,
Exchange Interactions in 24,133
Magnetic Properties of 24,133
Europous Oxide,
Ferromagnetic Resonance in 24,205
Paramagnetic Resonance in 24,205
Eutectic Formation in Ni Superalloys 23,537
Excess Current in Tunnel Diodes, Stress Induced 24,568
Exchange Interactions in:
EuS 24,133
Semiconductors 24,132
Exciton Absorption, Theory of 24,347
Exciton Scattering by Dislocations 23,947
Exciton Structure of:
Alkali Halides 23,841
Inert Gases (Solid) 23,841
Excitons, Zeeman and Stark Effects of 23,919
Excitons in:
Group II-VI Compounds, Condensation of 23,920
Molecular Crystals, Diffusion of 23,948

F

F-Centers,
Electron Tunneling from 24,073
Raman Effect in 24,363
Schottky Ionization from 24,073
Tunneling from Excited 24,073
F-Centers in:
Alkali Halides,
Concentration Dependence on Flow Stress of 24,532
Luminescence Life Time of 24,402
Production-Destruction by X-Rays of 23,636
Spin Resonance of 24,265
KBr,
Generation by Electrons and X-Rays of 23,637
X-Ray Induced 23,642
KCl 23,646
KCl,
Absorption of 24,345
Annealing of 23,645
Defect Effects on 23,643
Generation by Electrons and X-Rays of 23,637
Growth of 23,645
Impurity Effects on 23,644
KI, Formation of 23,641
LiF, Generation by Electrons and X-Rays of 23,637
NaCl,
Defect Effects on 23,640
Generation by Electrons and X-Rays of 23,637
Luminescence of 24,403
NaN_3 23,638
RbBr:Na, Absorption of 24,346
RbCl:Na, Absorption of 24,346
Fabrication of InP Laser Diodes 24,627
Fabry-Perot Resonators for Lasers 24,671
Facets on Ag, Decoration of 23,821
Faraday Ellipticity, Measurement of 24,451
Faraday Rotation, Quantum Theory of 24,449
Faraday Rotation in:
GaAs 24,450
GaSb 24,450
Ge 24,450
InAs 24,450
InSb 24,450, 24,451
Semiconductors 24,450
Fatigue Structure of Al-Mg 23,652
Faults in Au-Cd 23,715
fcc Alloys, Stacking Faults in 23,687
fcc Metals,
Dislocation Mobility in 23,670
Equation of State for 23,521
Stacking Fault Energy of 23,690
Feedback Amplifiers 24,727
Feedback Stabilization of Amplifiers 24,710
Fermi Level of Si 23,974
Fermi Surface, Determination of the 24,232, 24,233
Fermi Surface of:
Be 23,846
Bi, Shape of the 24,314
Ca 23,852
Ce 23,849
Cs 23,870
Gd 23,849
Graphite 23,847
K 23,870
Li 23,848
Mo 23,854, 24,227
Na 23,850, 23,851
Pb 23,853
Rb 23,870
Re 24,315
W 23,854, 24,227
Yb 23,849
Ferric Oxide, Ferromagnetic Resonance Linewidth of 24,217
Ferrimagnetic:
SbIG 24,122
V Garnets 24,121
Ferrite Foils, Phase Transistions in 23,552
Ferrites,
Dislocations in 23,661
Magnetic Properties of 24,111
Preparation of 23,799
Spin-Waves in 24,141
Ferroelectric - See Also Dielectric
Ferroelectric (Ba-Ca)TiO_3, Irradiation Effects on 23,898
Ferroelectric (Ba-Pb)TiO_3, Irradiation Effects on 23,898
Ferroelectric $(Ba_{1-x}R_{2x/3})Nb_2O_6$ 23,900
Ferroelectric $BaTiO_3$ 23,806
Ferroelectric $BaTiO_3$, Irradiation Effects on 23,8
Ferroelectric LHzS 23,903
Ferroelectric $NaNbO_3$ 23,901
Ferroelectric TGS 23,904
Ferroelectric WO_3 23,899
Ferroelectric $ZrTiO_3$, Irradiation Effects on 23,89
Ferroelectric and Antiferromagnetic Properties in Perovskite-Type Crystals, Coexistence of 24,088
Ferroelectric Arrangements in AO_3-Type Crystals 23,899
Ferroelectric Ceramics,
Domains in 23,911
Polarization of 23,910
Ferroelectric Storage Element, $BaTiO_3$ 23,806
Ferroelectric Transformations 23,897
Ferroelectric Transitions in GSN 23,902
Ferroelectrics, Polarization of 23,909
Ferromagnetic:
(Ce-Gd) Ru 24,124
$Dy_{5.07}Pd_{1.93}$ 24,126
Eu:
Chalcogenides 24,125
Halogens 24,125
Silicates 24,125
Gd_4Bi_3 24,127
Gd_5Pd_2 24,126
Gd_4Sb_3 24,127
Gd_4Se_3 24,127
$Ho_{5.04}Pd_{1.96}$ 24,126
Metals,
Nernst-Ettingshaussen Effect in 24,501, 24,502
Thermal:
Conductivity of 24,477
EMF of 24,496
Thermoelectric Properties of 24,497
$MnYO_3$ 24,096
$Tb_{5.1}Pd_{1.9}$ 24,126
Transition Metals, Magnetic Carriers in 24,1
$Y_{0.5}Gd_{1.6}Se_{2.9}$ 24,127
Ferromagnetic Exchange 24,091
Ferromagnetic Exchange Interactions in Semiconductors 24,132
Ferromagnetic Films,
Damping in 24,147
Ferromagnetic Resonance:
Linewidth in 24,215
Linewidth of 24,213
Gyromagnetic Ratio of 24,147
Magnetic Anisotropy of 24,181
Magnetization:
of 24,146, 24,148, 24,213
Curling in 24,172
Reversal in 24,147
Ripple in 24,173
Ferromagnetic Permeability of YIG 24,170
Ferromagnetic Relaxation 24,212
Ferromagnetic Relaxation, Green Function Theo of 24,210
Ferromagnetic Resonance,
Orientation Dependence of 24,200
Theory of 24,199
Ferromagnetic Resonance in:
EuO 24,205
Gd 24,202
Iron Garnets: Rare Earth 24,209
MnBi Films 24,452
$MnFe_2O_4$ 24,218
$Mn_xFe_{3-x}O_4$ 24,204
Ni-Fe Films 24,203
Y Garnet 24,208
YIG,
Domain Effects on 24,214
Pumping of 24,224

rromagnetic Resonance Line Width in:
Co 24,216
Fe 24,216
Fe_2O_3 24,217
Films 24,213, 24,215
$MnCO_3$ 24,217
Mn Ferrite 24,219
Ni 24,216
NiF_2 24,217
Ni Ferrite 24,220
Permalloy 24,216
Si-Fe 24,216
Y Garnet 24,221
ZnY 24,206
rromagnetic Resonance Line Width Broadening 24,211
rromagnetic Susceptibility of:
Fe 24,171
Fe-V 24,171
rromagnetism,
Band Theory of 24,128, 24,129, 24,130
Cluster Theory of 24,134
Many Body Approach to 24,131
Oguchi Transformation in 24,135
Spin Systems Bloch Equations for 24,137
Spin-Waves in 24,139, 24,140, 24,141,24,144
Time-Correlations in Spin System 24,136
rromagnets,
Domain Walls in 24,151
Magnetic Saturation in 24,152
Magnetization:
of 24,151, 24,154
Reversal in 24,175
Magnetostriction in 24,165
Permeability of 24,165
Spin-Waves in Fe-Ni 24,145
rrous Chloride, Susceptibility of 24,084,24,085
eld Effect Transistor Choppers 24,772
eld Effect Transistors 24,590
ield Effect Transistors,
Application of 24,707
Characteristics of 24,591
Development of 24,589
Irradiation Effects on 24,592, 24,593
Small-Signal Theory of 24,588
ield Effect-Photo Transistors 24,608,24,609
ield Emission from Ge Films 24,065
ilaments, Growth of Mo 23,796
ilm Memory:
Units 24,806, 24,807
Units, Switching of 24,808
ilm Thickness, Measurement of 23,788
ilms,
Absorption in:
Al 24,328
In 24,328
Carrier Concentrations in $InAs_ySb_{1-y}$ 24,331
Conductivity of:
Al 24,036
SiO 23,887
Critical Temperature of:
Nb Superconducting 24,011
Ta Superconducting 24,011
V Superconducting 24,011
Crystal Structure of:
CdS 23,611
Co 23,609
GaAs 23,610
Nb Oxide 34,612
Pt-Al 23,613
Damping in Ferromagnetic 24,147
Dielectric Properties of SiO 23,887
Domain Wall Motion in Magnetic 24,194
Doping of Si 23,723
Effect Mass Ratio in $InAs_ySb_{1-y}$ 24,331
Energy:
Density in Superconducting 24,014
Gap of Superconducting 24,015
Ferromagnetic Resonance:
in MnBi 24,452
in Ni-Fe 24,203
Line Width of 24,213, 24,215
Films, (Cont'd)
Galvanomagnetic Size Effects in Al 24,036
Growth of:
B 23,807
$Co Fe_2O_4$ 23,798
$FeFe_2O_4$ 23,798
GaP 23,786
Ge 23,785
$NiFe_2O_4$ 23,798
Semiconductor 23,765, 23,782
Si 23,571, 23,783, 23,784
Gyromagnetic Ratio of Ferromagnetic 24,147
Hall Mobility of CdTe 23,950
Magnetic Anisotropy of:
Ferromagnetic 24,181
Ni-Fe 24,183
Magnetic Domain:
Structure in:
Co 24,191
Ni-Fe 24,192
Wall Creep in: 24,195
Ni-Fe 24,196
Walls in 24,197, 24,198
Magnetic Hysteresis in Co 24,189
Magnetic Order Permalloy 24,092
Magnetic Properties of: 24,114
Mo-Permalloy 24,117
Ni-Fe-Cr 24,115
Permalloy 24,113, 24,116
Magnetization:
Curling in Ferromagnetic 24,172
Reversal in:
Co-Ni-P 24,176
Ferromagnetic 24,147
Permalloy 24,178
Ripple in Ferromagnetic 24,173
Magnetization of: 24,213
Ferromagnetic 24,146, 24,148
Ni-Fe 24,203
Magneto-Optic Effect in MnBi 24,452
Mobility of InSb 23,942
Optical Constants of:
Al 24,328
In 24,328
Photoconductivity of:
CdS 24,413
KBr 24,426
KCl 24,426
RbI 24,426
RbCl 24,426
ZnO-Eosin 24,424
Photoemission from:
Au 24,063
Cu 24,063
Ge 24,063
Piezoresistivity of Ge 23,975
Precipitation of UC_2 in UC 23,757
Preparation of: 23,769
$In As_y Sb_{1-y}$ 24,331
Nb Superconducting 24,011
Ni-Fe-Cr 24,115
Superconducting 23,769
Ta Superconducting 24,011
UC 23,757
V Superconducting 24,011
Refractive Index of:
Al 24,328
In 24,328
$InAs_ySb_{1-y}$ 24,331
Resistivity of:
CdSe 23,949
CdTe 23,950
Ge 23,975
Secondary Electron Emission from:
Au 24,063
Cu 24,063
Ge 24,063
KBr 24,062
Spin-Wave Resonance in 24,222
Films, (Cont'd)
Spin-Waves in:
Co 24,144
Fe 24,144
Permalloy 24,144
Stacking Faults in:
Cu 23,692
Si 23,701
Surface Structure of Si 23,571
Superconducting Pb-Pt 24,012
Transitions in Superconducting:
Nb 24,013
Ta 24,013
V_3Ge 24,013
Transmission in $InAs_ySb_{1-y}$ 24,331
Tunneling in:
Nb Superconducting 24,011
Ta Superconducting 24,011
V Superconducting 24,011
Twinning in UC 23,757
Twins in Cu 23,692
Films on Al,
Electroluminescence of Anodic 24,074
Rectification in Anodic 24,074
Filters,
Bandpass 24,769
Crystal 24,770
YIG 24,769
Filters for:
Lasers 24,673, 24,674
Lasers, Mica 24,675
Flame Fusion Growth of Oxide Crystals 23,800
Flip-Flop Switching Circuits 24,752
Flow Stress of Al, Irradiation Effects on 24,524
Flowmeters, Magnetoelectric 24,842
Fluorescence of:
Alkali Halides:Eu^{2+} 24,337
CdSe, Splitting of 24,393
Cm, L- 24,392
$Gd_2O_3:Nd^{3+}$ 24,396
$LaAlO_3:Cr^{3+}$ 24,397
$MgF_2:Ni^{2+}$ 24,668
Pu, L- 24,392
Ra, L- 24,392
Rare Earth Oxide Phosphors 24,394
Th, L- 24,392
U, L- 24,392
$Y_2O_3:Nd^{3+}$ 24,669
Fluorescent Decay in Glass:Nd^{3+} 24,395
Flourine from Mo, Desorption of 23,816
Fluorine Ferrites, Magnetic Properties of 24,119
FM Preamplifiers 24,778
Foils,
Dislocation Configuration in Nb 23,711
Interstitials in:
Au 23,704
Nb 23,711
Phase Transitions in:
Austenite 23,552
Ferrite 23,552
Stacking Faults in Au 23,704
Twinning in Nb 23,711
Formation of NiC 23,534
Four-Layer Diodes, Switching Characteristics of 24,573
Fracture Strength of MgO 24,530
Free Energy of Formation of:
$CoMn_2O_4$ 23,625
NbC 23,527
TaC 23,527
VC 23,527
Free-Running Multivibrators 24,738
Frequency Converters, Parametric 24,762
Frequency Dividers 24,736
Frequency Multipliers 24,760, 24,761
Furnaces,
Carbon Arc 23,770
Heating Units for 23,773

G

Gadolinium,
Curie Temperature of 24,166
Electronic Structure of 23,849
Fermi Surface of 23,849
Ferromagnetic Resonance in 24,202
Magnetic Structure of 24,099
Magnetic Transitions in 23,966
Magnetization of 24,078, 24,162
Nernst-Ettingshausen Effect in 24,502
Resistivity of 23,966
Spin Configuration of 24,078
Susceptibility of 24,078
Gadolinium in Dy Ethyl Sulfate, Paramagnetic Resonance of 24,299
Gadolinium^{3+} in CaF_2, Paramagnetic:
Relaxation of 24,278
Resonance of 24,298
Gadolinium Antimonide (Gd_4Sb_3), Ferromagnetic 24,127
Gadolinium Bismuthide (Gd_4Bi_3), Ferromagnetic 24,127
Gadolinium-Dysprosium, Magnetic Structure of 24,100
Gadolinium Garnet, Magnetization of 24,161
Gadolinium Iron Garnet, Magnetostriction of 24,107
Gadolinium Orthophosphate, Susceptibility of 24,079
Gadolinium Oxide:Nd^{3+},
Emission from 24,396
Fluorescence of 24,396
Gadolium Palladium (Gd_5Pd_2), Ferromagnetic 24,126
Gadolinium Selenide (Gd_4Se_3),
Antiferromagnetic 24,127
Ferromagnetic 24,127
Gallium,
de Haas-van Alphen Effect in 24,316, 24,317
Heat Capacity of 24,463
Superconducting 24,463
Ultrasonic Absorption in 24,544
Gallium in Ge, Diffusion of 23,729
Gallium Antimonide,
Absorption in 24,421
Energy Band Structure of 23,977
Faraday Rotation in 24,450
Magnetoresistivity of 24,048
Phonon Scattering in 23,868
Photoconductivity of 24,421, 24,423
Piezoresistivity of 23,977
Resistivity of 23,977
Schubnikov-de Haas Effect in 24,048
Sputtering of 23,827
Thermal:
Conductivity of 23,868
Expansion of 24,491
Gallium Arsenide,
Absorption in 24,330
Conductivity Oscillations in 23,998
Defect Concentration in 24,480
Diffusion in 23,738
Diffusion of:
Ag in 23,744
S in 23,743
Se in 23,743
Te in 23,743
Zn in 23,739, 23,740, 23,741, 23,742
Distribution Coefficient of Zn in 23,740
Effective Mass of Electrons in 23,932
Energy Band Structure of 23,844
Faraday Rotation in 24,450
Hall Effect in 23,844, 23,976
Phonon Scattering in 23,868
Piezoresistivity of 23,976
Preparation of 23,778
Refractive Index of 24,444
Resistivity of 23,976
Solubility of:
Ag in 23,744
Zn in 23,740
Gallium Arsenide, (Cont'd)
Surface States of 23,857
Thermal Conductivity of 23,868, 24,480
Gallium Arsenide Diodes, Luminescence of 24,368
Gallium Arsenide Films, Crystal Structure of 23,610
Gallium Arsenide Laser Diodes 23,739, 24,624
Gallium Arsenide Laser Diodes,
Analysis of 24,620
Harmonic Generation in 24,626
Mode Spectra of 24,622
Near-Field Patterns in 24,623
Response of 24,621
Gallium Arsenide Transistors, Diffused 23,743
Gallium Arsenide-Phosphide, Preparation of 24,625
Gallium Arsenide-Phosphide Laser Diodes, Characteristics of 24,625
Gallium Phosphide,
Absorption in 24,401
Crystal Structure of 23,577
Diffusion of Zn in 23,740
Distribution Coefficient of Zn in 23,740
Energy Gap of 24,422
Junction Formation in 23,577
Luminescence Edge in 24,401
Phase Transistions in 23,577
Photoconductivity of 24,422
Solubility of Zn in 23,740
Gallium Phosphide Diodes,
Luminescence in 24,369
Radiation from 24,370
Gallium Phosphide Films, Growth of 23,786
Gallium Phosphide Solar Cells 23,786
Gallium Selenide, Photoconductivity of 24,420
Gallium-Niobium Oxides,
Crystal Structure of 23,886
Dielectric Properties of 23,886
Galvanomagnetic Properties of:
Be 23,957
Graphite 24,035
InSb Layers 24,034
Mo 23,957
Pd 23,957
Rh 23,957
Galvanomagnetic Size Effects in Al Films 24,036
Garnets, Magnetization of 24,153
Gate Turn-Off Diodes, Characteristics of 24,574
Generators,
Code 24,803
Pulse 24,763
Square Wave 24,736
Germanium,
Acoustoelectric Effect in n-Type 24,072
Attenuation of Elastic Waves in 24,507
Carrier Density in 24,057
Conduction in 23,953
Conductivity of 23,965
Crystallization of Amorphous 23,776
Cyclotron Resonance Line Broadening in 24,057
Decoration of 23,820
Diffusion of:
As in 23,729
Ga in 23,729
In in 23,729
Sb in 23,729, 23,730, 23,733
Ta in 23,734
Dislocation Distribution in 23,685
Dislocations in 24,522
Effective Mass of Electrons in 23,932
Electron:
Diffraction Streak Patterns in 23,563
Recombination in 23,925, 23,929
Electronic Structure of 23,872
Etching of 23,819
Faraday Rotation in 24,450
Glide in 24,522
Grüneisen Constant of 24,490
Hall Coefficient of 23,965, 24,044
Impurity Band in 23,840
Interaction with Aqueous Solutions of 23,812
Interstitials 23,631
Magnetoresistivity of 24,044
Germanium, (Cont'd)
Nernst-Ettingshausen Effect in n-Type 24,50
Optical Modulation in 24,454, 24,455
Paramagnetic Resonance of Donors in 24,267
Photoconductivity of 23,929, 24,409, 24,41
Photoelasticity in 24,507
Photomagnetic Effects in 24,429
Piezoresistance of 23,840
Plastic Deformation in 24,522
Radiation from 24,367
Recombination:
Centers in 23,924
Cross Sections in 23,929
in 23,925
Resistivity:
of 24,044
Oscillations in 23,999
Scattering of Electrons in 23,945
Surface States of 23,858
Susceptibility of 24,258
Thermal:
Emf in 24,500
Expansion of 24,490
Thermoelectric Power of Hot Carriers in 24,4
Vacancies in 23,631
Web Growth of 23,777
Work Hardening in 23,685
Zone Melting of 23,763
Germanium: Sn, Absorption in 24,327
Germanium on Cu, Diffusion (Surface) of 23,73
Germanium Films,
Field Emission from 24,065
Growth of 23,782, 23,785
Photoemission from 24,063
Piezoresistivity of 23,975
Resistivity of 23,975
Secondary Electron Emission from 24,063
Germanium Planar Transistors 24,599
Germanium Power Transistors, Life Tests on 24,5
Germanium-Bromine, Equilibria in 23,787
Germanium Dioxide,
Heat of Formation of 23,525
Paramagnetic Resonance of V in 24,286
Germanium-Gallium Arsenide Heterojunctions, Characteristics of 24,564
Germanium Iodide, Chemical Equilibria in 23,72
Germanium-Iodine, Equilibria in 23,787
Germanium Nickel Oxide ($GeNi_2O_4$),
Antiferromagnetic 24,096
Magnetic Structure of 24,096
Germanium Telluride,
Carriers in 23,917
Energy Band Structure of 24,435
Heat of Formation of 23,522
Partial Pressure of 23,528
Reflection from 24,435
Transmission in 24,435
Vaporization of 23,522
Germanium Telluride Superconductors 24,032
Glass, Diffusion of Fe in 23,750
Glass:Nd Lasers 24,667
Glass:Nd Lasers, Thermal Effects in 24,643
Glass:Nd^{3+}, Fluorescent Decay in 24,395
Glass:Nd^{3+} Lasers 24,666
Glide in Ge 24,522
Glide Bands in MgO 24,530
Glide Planes in SnS_2 23,705
Glycine Silver Nitrate, Ferroelectric Transitions 23,902
Gold,
Dislocation Peaks in 24,551
Electron Diffraction Streak Patterns in 23,563
Internal Friction in 24,551, 24,552
Interstitial Migration in 23,635
Stacking Faults in 23,629
Twin Boundary Annealing in 23,707
Vacancies in 23,629
Vacancy:
Annealing in 23,627
Cluster at Twin Boundaries in 23,707
Young's Modulus of 24,516

Gold Films,
  Photoemission from 24,063
  Secondary Electron Emission from 24,063
Gold Foils,
  Interstitials in 23,704
  Stacking Faults in 23,704
Gold Antimonide,
  Conductivity of 23,994
  Hall Coefficients of 23,994
  Thermoelectric Power of 23,994
Gold-Cadmium,
  Faults in 23,715
  Lattice Spacing in 23,715
Gold Manganese (Au_3Mn), Crystal Structure of 23,605
Gold-Palladium, Order in 23,557
Gold-Silicon,
  Energy Band Structure of 24,069
  Surface Barrier of 24,069
Gold-Titanium Dioxide Rectifiers, Characteristics of 24,562
Goniometers 23,823, 23,824
Graded Base Transistors, Characteristics of 24,587
Grain Boundaries in Zn, Elimination of 23,789
Grain Boundary Conductance in InSb 23,980
Grain Boundary Diffusion of Ni in MgO 23,746
Grain Boundary Mobility, Impurity Effects on 23,706
Graphite,
  Defects in 23,620
  Effective Mass in 23,847
  Fermi Surface of 23,847
  Galvanomagnetic Properties of 24,035
  Magnetoresistivity of 23,847
  Resistivity of 23,963
Gray Code Converters 24,821
Grounded Emitter Circuits, Switching Time of 24,750
Group I-VIII Compounds,
  Crystal Structure of 23,577
  Junction Formation in 23,577
  Phase Transitions in 23,577
Group II-VI Compounds,
  Crystal Structure of 23,577
  Exciton Condensation in 23,920
  Junction Formation in 23,577
  Phase Transitions in 23,577
Group III-V Compounds,
  Crystal Structure of 23,577
  Junction Formation in 23,577
  Phase Transitions in 23,577
  Surface States in 23,856
Group IV-VI Compounds,
  Energy Band Structure of 24,435
  Reflection from 24,435
  Transmission in 24,435
Group V Semimetals,
  Energy Band Structure of 24,435
  Reflection from 24,435
  Transmission in 24,435
Growth,
  Electrolytic 23,771
  Epitaxial 23,764
  Prediction of Segregation in Crystal 23,759
Growth from the Melt, Liquid Mixing in 23,759
Growth of:
  - See Also Preparation of
  Al-Cu 23,790
  Al_2O_3 24,662
  B Films 23,807
  Bi 23,792
  $BaTiO_3$ 23,805, 23,806
  CdI 23,578
  $CoFe_2O_4$ 23,798
  Co:
    Oxide 23,797
    Whiskers 23,795
  Crystals, Vapor-Liquid-Solid: 23,767
    Mechanism of 23,768
  Cu 23,790
  $FeFe_2O_4$ 23,798
Growth of: (Cont'd)
  Fe Whiskers 23,569
  GaP Films 23,786
  Ge Films 23,785
  K 23,789
  LaF_3 23,803
  Mo Filaments 23,796
  Mo-Fe 23,790
  Na 23,789
  $NiFe_2O_4$ 23,798
  Oxide Crystals 23,800
  Rare Earth-NaMo Scheelites 23,801
  Ruby 24,662
  Semiconductor:
    Films 23,782
    Films, Bibliography on 23,765
  Semiconductors,
    Supersaturation During 23,775
    Web 23,777
  Si:
    Films 23,571, 23,783, 23,784
    Whiskers 23,768
  Sn Whiskers 23,794
  YIG 23,804
  Zn, Dislocation Free 23,791
  ZnSb 23,939, 24,323
  $ZnWO_3$ 23,802
  ZnY 24,206
  Zr Whiskers 23,793
Growth Techniques, Survey of 23,766
Grueneisen Constant of:
  Cd 24,489
  Cu 24,490
  CsBr 24,474
  Ge 24,490
  In 24,489
  KBr 24,474
  KCl 24,474
  NaCl 24,474
Guinier-Preston Zones in Al-Ag 23,532, 23,533
Gyromagnetic Ratio in Ferromagnetic Films 24,147

H

Hafnium Carbide, Heat Content of 24,470
Hafnium Stannide, Crystal Structure of 23,586
Hall Coefficient of:
  $(Ag_2Te)_{0.41}-(Sb_2Te_3)_{0.59}$ 23,781
  $AuSb_2$ 23,994
  Bi, Grain Size Dependence of 23,981
  Bi-Sb,
    Grain Size Dependence of 23,981
    Temperature Variation of 24,045
  Bi_2Te_3 24,052
  $CrSi_2$ 23,993
  Cu_2Sb 23,994
  Ge 24,044
  Ge, Temperature Dependence of 23,965
  Organic Semiconductors 23,938
  PbTe-SnTe 23,832
  Si Measured During Irradiation 24,051
  $SrTiO_3$ 23,992
  TiO_2, Temperature Variation of 24,054
  ZnSb 23,939
Hall Effect in:
  GaAs 23,844, 23,976
  InSb 24,053
  Low Mobility Semiconductors 24,050
  NiO(Li) 23,941
  TiC_xN_{1-x} 24,055
  $TiV_{1-x}C$ 24,055
  Zn_3Sb_2 24,075
Hall Mobility of:
  CdS 23,939
  CdTe Films 23,950
  UO_2 23,987
  ZnSb 24,323
Hardening in:
  Alkali Halides, Radiation 24,532
  Cu, Strain 24,533
Heat Capacity - See Also Specific Heat; Debye Temperature
Heat Capacity of:
  Ag 23,866
  Cd 24,463
  Cs 24,460
  Cu 24,463
  Ga 24,463
  H(Solid) 24,461
  K 24,460
  Pb 23,866
  Rb 24,460
  U 24,467
  UC 24,468
  U-Fission Alloys 24,467
  WC 24,470
Heat Content of HfC 24,470
Heat Flow, Theory of 24,475
Heat of Formation of:
  BeCl 23,524
  GeO_2 23,525
  GeTe 23,522
  P Oxides 23,523
Heat of Solution of:
  Sn-Ag Alloys 23,530
  Sn-Al Alloys 23,531
  Sn-Ga Alloys 23,531
  Sn-In Alloys 23,531
  Sn-Rare Earth Alloys 23,530
Heating Units 23,773
Heisenberg Antiferromagnets,
  Low Temperature Properties of 24,235
  Variational Treatment of 24,234
Heisenberg Ferromagnets,
  Specific Heat of 24,138
  Spin-Waves in 24,138
Helicon Waves in:
  Anisotropic Solids 24,233
  Metals 24,232
Helicon-Phonon Interactions in Metals 24,231
$Helium^3$ (Solid), NMR in 24,303
Hematite, Magnetic:
  Anisotropy in 24,188
  Properties of 24,188
Heterodyne Techniques for Lasers 24,650
Heterojunctions,
  Electroluminescence of:
    Cu_2S-ZnS 24,372
    Cu_2Se-ZnSe 24,372
  Ge-GaAs 24,564
High Impedance Amplifiers 24,732
High Temperature-Pressure Apparatus 23,772
Hole Scattering, Relaxation in 23,946
Holmium, Magnetization of 24,087
Holmium Palladium ($Ho_{5.04}Pd_{1.96}$), Ferromagnetic 24,126
Hot Carriers in Ge, Thermoelectric Power of 24,499
Hot Electrons, Cyclotron Resonance of 24,056
Hydrogen (Solid), Heat Capacity of 24,461
Hydrogen Sulfide (Solid),
  Crystal Structure of 23,580
  Phase Transformation in 23,580
Hysteresis in Co Films 24,189

I

Impedance Converters 24,767
Impedance Converters, Negative 24,768
Impurity Analysis, γ-Ray Spectrometry in 23,717
Impurity Band in Ge 23,840
Impurity Conduction in Semiconductors 23,952
Indium,
  Grueneisen Constant of 24,489
  Thermal Expansion of 24,489
Indium in Ge, Diffusion of 23,729
Indium Films,
  Absorption in 24,328
  Refractive Index of 24,328
  Optical Constants of 24,328
Indium Plates,
  Magnetoresistivity of 24,046
  Resistivity of 24,046

Indium Antimonide,
Carrier Density at Grain Boundaries of 23,980
Casting of 23,779
Conductivity at Grain Boundaries of 23,980
Effective Mass of Electrons in 23,932
Energy Gap of 24,053
Faraday Rotation in 24,450, 24,451
Hall Effect in 24,053
Interstitial-Vacancy Pairs in 23,632
Magnetoresistivity of 24,000
Mobility at Grain Boundaries of 23,980
Phase:
Diagram of 23,549
Transformations of 23,549
Phonon Scattering in 23,868
Photomagnetic Effect in 24,430
Resistivity of 23,983, 24,000
Thermal Conductivity of 23,868
Web Growth of 23,777
Indium Antimonide Corbino Disks, Magnetoresistivity of 24,047
Indium Antimonide Films, Mobility of 23,942
Indium Antimonide Laser Diodes, Magnetic Field Effects on 24,629
Indium Antimonide Layers,
Galvanomagnetic Properties of 24,034
Optical Properties of 24,034
Indium Antimonide Superconductors 24,031
Indium Arsenide,
Absorption in 24,353
Effective Mass of Electrons in 24,931, 24,932
Faraday Rotation in 24,450
Lifetime of 24,923
Photoluminescence of 24,391
Indium Arsenide Laser Diodes, Characteristics of 24,628
Indium Arsenide-Antimonide Films,
Carrier Concentrations in 24,331
Effective Mass Ratio in 24,331
Preparation of 24,331
Refractive Index of 24,331
Transmission in 24,331
Indium-Lead Superconductors, Critical Fields in 24,019
Indium Phosphide,
Conductivity Oscillations in 23,998
Seebeck Coefficient of 24,481
Thermal Conductivity of 24,481
Indium Phosphide Laser Diodes,
Characteristics of 24,627
Fabrication of 24,627
Harmonic Generation in 24,626
Indium Telluride,
Crystal Structure of 23,575
Nuclear Magnetic Relaxation in 24,312
Preparation of 23,575
Indium Telluride in:
PbTe, Solubility of 23,535
SnTe, Solubility of 23,535
Indium Trisulfide,
Conductivity of 23,834
Dielectric Constant of 23,834
Infrared Emission from 23,834
Photoconductivity of 23,834
Preparation of 23,834
Refractive Index of 23,834
Thermoelectric Power of 23,834
Inductors in Integrated Circuits 24,696
Inductors for Thin Film Circuits 24,695
Inert Gases (Solid),
Energy Band Structure of 23,841
Exciton Structure of 23,841
Properties of 23,831
Infrared Absorption,
Temperature Dependence of 24,349
Theory of 24,348
Infrared Absorption in:
InAs 24,353
KCl:Te 24,356
La Superconductors 24,351
Mica 24,352
Infrared Absorption in: (Cont'd)
NaCl:Te 24,356
$NaNO_2$ 24,354
Si:(B,Li) 24,350
Infrared Electroluminescence of Cu_2O 24,381
Infrared Emission from InS_3 23,834
Infrared Lasers 24,629
Infrared Modulation in Ge 24,454, 24,455
Infrared Reflection from:
CoO 24,440
MnO 24,440
NiO 24,440
Infrared Transmission in:
BaF_2 24,355
CoF_2 24,250
MgO 24,355
$MnCO_3$ 24,250
NiF_2 24,250
Injection Electroluminescence of:
Cu_2S-ZnS Heterojunctions 24,372
Cu_2Se-ZnSe Heterojunctions 24,372
Injection Luminescence of GaAs Diodes 24,368
Insulators, Thermal Diffusivity of 24,485
Integrated Amplifiers 24,727
Integrated Circuits 24,691
Integrated Circuits,
Design of 24,690
Inductors In 24,696
Reliability of 24,692
Technology of 24,689
Integrated Circuits for Radar Systems 24,693
Integrated Counters 24,798
Interfaces,
Energy States at 23,855
Melt/Solid 23,759
Intermetallic Compounds, Neutron-Activation Analysis of 23,561
Internal Friction, Calculation of 24,514
Internal Friction in:
Ag 24,551
AgCl 24,557
Au 24,551, 24,552
Cu 24,551
Mo 23,796
Nb 24,553, 24,554, 24,555
Pt 24,551
Ta 24,555
Internal Friction-Plastic Deformation Relations 23,647
Interstitials in:
Al 24,524
Al-Zn, Radiation Induced 23,753
Au, Migration of 23,635
Au Foils 23,704
Diamond 23,631
Fe 23,634
Ge 23,631
NaCl, Energies of Cl 23,633
Nb Foils 23,711
Si 23,631
Ta, Interaction Between Dislocations and 23,682
W, Interaction Between Dislocations and 23,682
Interstitial Diffusion in GaAs 23,738
Interstitial-Vacancy Pairs in InSb 23,632
Ion Emission from Ta 24,066
Ionic Charge in ZnS 23,842
Ionic Conductivity of:
CaO-Y_2O_3-ZrO_2 23,989
KCl 23,990
ZrO-CaO 23,988
Ions, Effective Charge of 23,933
Iron,
Crystal Structure of 23,564
Diffusion of C in 23,747
Dislocations in Deformed 23,657
Electron Diffraction Streak Patterns in 23,563
Ferromagnetic Resonance Line Width in 24,216
Interstitials in 23,634
Magnetic Properties of 24,112
Magnetization of 24,156
Nernst-Ettingshausen Effect in 24,502
Iron, (Cont'd)
Precipitation of:
C in 23,971
Nitrides in 23,754
Resistivity of 23,971
Susceptibility of 24,171
Vacancies in 23,634
Yielding in 24,531
Iron in:
Glass, Diffusion of 23,750
MgO, Diffusion of 23,749
$Iron^{2+}$ in:
CaO, Paramagnetic Resonance of 24,294
MgO, Paramagnetic Resonance of 24,295
$Iron^{3+}$ in:
Al_2O_3, Paramagnetic Relaxation of 24,271
Calcite, Paramagnetic Resonance Absorption of 24,280
CaF_2, Paramagnetic Resonance of 24,293
$K_3(Co,Fe)(CN)_6$, Paramagnetic Relaxation of 24,296
TmAl, Paramagnetic Spin-Lattice Relaxation of 24,274
TmGa, Paramagnetic Spin-Lattice Relaxation of 24,274
Iron Films,
Spin-Waves in 24,144
Iron Whiskers,
Growth of 23,569
Surface Structure of 23,569
Iron Aluminum, Magnetic Fields in 24,105
Iron Chromium Boride, Crystal Structure of 23,599
Iron Chromium Oxide ($FeCr_2O_4$), Magnetic Structure of 24,098
Iron Chromium Sulfide ($FeCr_2S_4$), Magnetic Structure of 24,098
Iron-Cobalt, Diffusion of C in 23,747
Iron Ferrite Films, Growth of 23,798
Iron Garnet:Rare Earths, Ferromagnetic Resonance of 24,209
Iron Group Impurities in:
ZnO, Paramagnetic Resonance of 24,283
ZnS, Paramagnetic Resonance of 24,283
Iron-Manganese-Silicon, Crystal Structure of 23,600
Iron Molybdenum Carbide, Crystal Structure of 23,598
Iron-Nickel,
Magnetic Order in 24,097
Magnetization of 24,163
Spin-Waves in 24,145
Iron Niobium Oxide ($FeNbO_4$),
Crystal Structure of 23,597
Polymorphic Types of 23,597
Iron-Rhodium, Magnetic Moments in 24,106
Iron-Silicon, Cleavage Cracks in 23,714
Iron Sodium Oxide ($FeNaO_2$),
Antiferromagnetic 24,096
Magnetic Structure of 24,096
Iron Sulfide,
Lattice Parameters of 23,606
Thermal Expansion of 23,606
Iron-Vanadium, Susceptibility of 24,171

J

Junction Formation in:
CdS 23,577
CdTe 23,577
GaP 23,577
Group:
I-VIII Compounds 23,577
II-VI Compounds 23,577
III-V Compounds 23,577
ZnS 23,577

K

K-Band Amplifiers, Parametric 24,717
Knight Shifts, Calculations on 24,305
Kyanite, Paramagnetic Resonance of Cr^{3+} in 24,288

L

anthanum, Nuclear Magnetic Relaxation in 24,311
anthanum Superconductors,
  Absorption in 24,351
  Energy Band Structure of 24,007
  Model for 24,007
anthanum Aluminate:Cr^{3+}, Fluorescence of 24,397
anthanum Trifluoride, Growth of 23,803
aser - See Also Maser
aser Applications in:
  Breakdown of Gases 24,856
  Communication Systems 24,789
  Computer Circuitry 24,822
  Medicine 24,854
  Metal Working 24,853
  Optical Logic 24,792
  Plasma Physics 24,855
  Ranging Systems 24,789, 24,790, 24,791
  Scattering in Gases 24,857
aser Beat Detecting Photodiodes 24,606
aser Diodes,
  Analysis of 24,620
  Characteristics of 24,625, 24,627
  Fabrication of 24,625, 24,627
  GaAs 24,620, 24,621, 24,622, 24,623,24,624, 24,626
  $Ga(As_{1-x}P_x)$ 24,625
  Harmonic Generation in 24,626
  InAs 24,628
  InP 24,626, 24,627
  InSb 24,629
  Magnetic Field Effects on 24,629
  Mode Spectra of 24,622
  Near-Field Patterns in 24,623
  Quantum Efficiency of 24,619
  Response of 24,621
  SiC 24,630
aser Display Systems 24,822
aser Induced Ultrasonic Waves in Dielectrics 24,535
aser Observation of Two-Photon Excitations 24,332
aser Pulse Detectors 24,640
aser System, 4-Level 24,364
asers,
  Amplitude Variations in 24,616
  Beam:
    Cross Section of 24,639
    Steering of 24,652, 24,653
  Bibliography on 24,631, 24,632
  $CaF_2:Dy^{2+}$ 24,648
  $CaWO_4$:Nd 24,649
  Characteristics of 24,661
  Crystal Property Dependence of 24,644
  Double Resonance in 24,654
  Filters for 24,673, 24,674, 24,675
  Five Layer Calculations on 24,642
  GaAs Diode 23,739
  Giant Pulse 24,637
  Glass:Nd 24,643, 24,667
  Glass:Nd^{3+} 24,666
  Ground State Population of 24,646
  Heterodyne Techniques for 24,650, 24,651
  Infrared 24,629
  Injection 24,443
  Material Criteria for 24,664
  $MgF_2:Ni^{2+}$ 24,668
  Modulation Techniques for 24,650, 24,651
  Modulators for 24,676, 24,677, 24,678
  Noise in 24,640, 24,641
  Oscillations in 24,655, 24,656
  Output Parameters of 24,663
  Perturbation Energy in 24,638
  Photometer for 24,670
  Photon Avalanches from 24,636
  Power Supply for 24,678
  Pulse/Amplitude Modulated 24,389
  Pumping in 24,649
  Pumping of 24,647
  Radiation Buildup in 24,637
  Resonators for 24,671, 24,672
Lasers, (Cont'd)
  Review on 24,633
  Ruby 24,389, 24,617, 24,645, 24,646, 24,649 24,655, 24,656, 24,657 24,658, 24,659, 24,660, 24,662, 24,663, 24,672
  Semiconductor 24,665
  Spacing of the Emission Lines of GaAs 24,444
  Spiking in 24,658, 24,659
  Spikes in Q-Tuned 24,657
  Stokes Shift in 24,660
  Sun-Pumped 24,648
  Theory of 24,634, 24,635
  Thermal Effects in 24,643
  Ultrasonic Produced Oscillations in 24,645
Latent Heat, Calorimeter for Measuring 24,458
Lattice Expansion in Al-Ag 23,625
Lattice Parameters of:
  Ag-Sn-Cd 23,608
  Bi_2Te_3 23,601
  CoS_2 23,606
  Cu, High Temperature 23,603
  Cu-Si-Zn 23,604
  FeS_2 23,606
  Sn-Cd 23,607
  ZnSe 23,602
Lattice Spacing in Au-Cd 23,715
Lattice Vibrations - See Also Phonons
Lattice Vibrations, Deformation Dependence of 23,862
Lattice Vibrations in:
  Ag 23,866
  $BaTiO_3$ 23,864
  Defect Crystals 23,860
  Nonideal Lattices 23,859
  Pb 23,866
  Wurtzite Crystals 23,865
  Zinc Blende Crystals 23,865
  ZnS-type Crystals 23,863
Lattice Vibrations of Disordered Chains 23,860
Layers, Diffusion in Epitaxial 23,728
Lead,
  Effective Mass in 23,853
  Fermi Surface of 23,853
  Heat Capacity of 23,866
  Lattice Vibrations in 23,866
Lead in Ag-Sb-Te, Distribution of 23,536
Lead Nitrate, Paramagnetic Resonance in 24,281
Lead-Group VI Compounds,
  Energy Band Structures of 24,435
  Transmission in 24,435
Lead-Indium Superconductors, Transitions in 24,017
Lead-Platinum Superconducting Films 24,012
Lead Selenide,
  Energy Band Structure of 24,435
  Piezoresistivity of 23,978
  Polymorphic Transformation in 23,978
  Reflection from 24,435
  Resistivity of 23,978
  Transmission in 24,435
Lead Sulfide,
  Absorption in 24,357, 24,431
  Cyclotron Mass of 24,040
  Dislocations in 23,660
  Energy Band Structure of 23,838, 24,040, 24,435
  Magnetoresistivity of 24,040
  Optical Constants of 24,431
  Piezoresistivity of 23,978
  Polymorphic Transformation in 23,978
  Reflection from 24,435
  Refractive Index of 24,431
  Resistivity of 23,978
  Schubnikov-de Haas Effect in 24,040
  Transmission in 24,435
  Ultrasonic Wave Velocity in 24,548
Lead Telluride,
  Energy Band Structure of 24,435
  Dielectric Constant of 23,888
  Piezoresistivity of 23,978
  Polymorphic Transformation in 23,978
Lead Telluride, (Cont'd)
  Preparation of Fine-Grained 23,780
  Radiation from 24,371
  Reflection from 24,435
  Resistivity of 23,978
  Solubility of:
    CdTe in 23,535
    InTe in 23,535
  Transmission in 24,435
  Transport in 23,940
Lead-Thallium Superconductors, Critical Field of 24,020
Lead-Tin Solders, Specific Heat of 24,464
Lead-Tin Telluride,
  Hall Coefficient of 23,832
  Resistivity of 23,832
  Seebeck Coefficient of 23,832
  Thermal Resistivity of 23,832
Lead Zirconate-Titanate, Piezoelectric 23,915
Life Tests on Ge Power Transistors 24,576
Lifetime - See Also Recombination
Lifetime of:
  InAs, Temperature Dependence of 23,923
  Semiconductors 23,843
Lighting Controls 24,834
Lighting Controls, Flash Tube 24,835
Lithium,
  Conductivity of 23,973
  Fermi Surface of 23,848
Lithium Aluminum Oxide ($LiAl_5O_8$), Nuclear Quadrupole Coupling in 23,878
Lithium Ferrite, Magnetoacoustic Resonance in 24,228
Lithium Fluoride,
  Color Center Generation in 23,637
  Dislocation:
    Jumps in 23,671, 23,672
    Motion in 23,673
  F-Center Generation in 23,637
Lithium Hydrazinium Sulfate, Ferroelectric 23,903
Lithium Tri-Hydrogen Selenite, Dislocation Etching of 23,654
Logic Circuits,
  Clareed Module 24,795
  DCTL 24,794
  Micro- 24,793
Logic Diodes 24,575
Logic System, Optical 24,792
Luminescence of:
  AgCl 24,338
  Alkali Halides,
    F-Centers 24,402
    Recombination 24,373
  GaAs Diodes, Injection 24,368
  GaP Diodes 24,369
  Mg_4GeO_6:Mn 24,404
  NaCl, F-Center 24,403
  ZnS:Cu Phosphors 24,406
  ZnS:Cu:Cl Phosphor, Variations in 24,405
Luminescence Edge in GaP 24,401

M

M-Centers in Alkali Halides, Production-Destruction by X-Rays of 23,636
Magnesium Alloys, Specific Heat of 24,471
Magnesium Aluminate Spinel, Cathodoluminescence of 24,388
Magnesium Fluoride:Ni^{2+},
  Fluorescence of 24,668
  Laser Oscillations from 24,668
Magnesium Germanate: Mn, Luminescence of 24,404
Magnesium-Iron Ferrite,
  Magnetic Order in 24,157
  Magnetization of 24,157
Magnesium Oxide,
  Cracks in 24,530
  Diffusion of:
    Fe in 23,749
    Ni in 23,746

Magnesium Oxide, (Cont'd)
Fracture Strength of 24,530
Glide Band Length of 24,530
Paramagnetic Resonance of:
Fe^{2+} in 24,295
Mn^{2+} in 24,292
V^{2+} in 24,287
Precipitates in 23,756
Strength of 24,528
Transmission in 24,355
Magnesium Sulfite Trihydrate, Crystal Structure of 23,593
Magnetic Susceptibility of:
Mo 24,259
Pt 24,259
Magnetic Alloy Films, Preparation of 23,769
Magnetic Anisotropy of:
Hematite 24,188
Ni-Co Ferrites 24,184
Ni-Fe, Temperature Dependence of 24,182
Ni-Fe:
Films 24,183
Ferrites 24,185
YIG:Si; Mn 24,186
YIG:Yb 24,187
Magnetic Card Memory Units 24,182
Magnetic Carriers in Ferromagnetic Transition Metals 24,143
Magnetic Core Memory Units 24,811
Magnetic Core Switching Circuits 24,754
Magnetic Dilute Systems, Superparamagnetism in 24,260
Magnetic Domain Structure in:
Co Films 24,191
Ni-Fe Films 24,192
Magnetic Domain Wall:
Creep in:
Films 24,195
Ni-Fe Films 24,196
Motion, Theory of 24,193
Magnetic Domain Walls in:
Films 24,198
Films, Measurement of 24,197
Magnetic Fields in FeAl 24,105
Magnetic Film Memory:
Units, Switching of 24,808
Units 24,806, 24,807
Magnetic Films,
Domain Wall:
Creep in 24,195
Motion in 24,194
Domain Walls in 24,197, 24,198
Spin-Wave Resonance in 24,222
Magnetic Hysteresis in Co Films 24,189
Magnetic Loss in Si Steels 24,180
Magnetic Moments of:
Fe-Rh 24,106
SmIG 24,104
Magnetic Order in:
$BiFeO_3$ 24,088
Fe-Ni 24,097
Mg-Fe Ferrite 24,157
Ni-Fe, Temperature Dependence of 24,182
Permalloy Films 24,092
$YMnO_3$ 24,088
Magnetic Properties of:
Cu (Impure) 24,123
Cu-Co 24,123
Cu-Fe 24,123
Eu 24,093
EuS 24,133
F Ferrites 24,119
Fe, Irradiation Effects on 24,112
Ferrites, Irradiation Effects on 24,111
Films, Aging Effects in 24,114
Hematite 24,188
Mo Permalloy, Irradiation Effects on 24,112
Mo-Permalloy: 24,118
Films 24,117
Ni-Fe-Cr Films 24,115
Magnetic Properties of: (Cont'd)
Permalloy Films,
Irradiation Effects on 24,113
Stress Effects on 24,116
Remendar 24,120
Magnetic Resonance, Modulation Effects in 24,201
Magnetic Resonance in Orthoferrites 24,207
Magnetic Saturation in Ferromagnets, Optical Measurement of 24,152
Magnetic Stacking Faults in K_2NiF_4 24,245
Magnetic States in Metals 24,091
Magnetic Structure,
Green's Function Analysis of 24,089
Theory of 24,090
Magnetic Structure of:
Ba-Zn Ferrites 24,190
Cr_3S_4 24,096
Cr_3Se_4 24,096
Cr_3Te_4 24,096
$FeCr_2O_4$ 24,098
$FeCr_2S_4$ 24,098
$FeNaO_2$ 24,096
Gd 24,099
Gd-Dy 24,100
$GeNi_2O_4$ 24,096
$MnYO_3$ 24,096
Nd 24,094
$TbMn_2$ 24,095
YIG (Ion Substituted) 24,167
Magnetic Susceptibility,
Defect Effects on 24,259
Measurement of 24,076
Magnetic Susceptibility of:
$CdS:Ni^{2+}$ 24,082
CoO 24,086
$CoTiO_3$ 23,591
Cr-Acetic Acid Salts 24,084
CrI_2, Temperature Dependence of 24,083
$FeCd_2 \cdot 4H_2O$ 24,084
$FeCl_2$-$4H_2O$ 24,085
Gd 24,078
$GdPO_4$ 24,079
Mo 24,259
Mo-Tc 24,080
Orthoferrites 24,207
Pt 24,259
Rare Earth-NaMo Scheelites 23,801
$ZnO:Ni^{2+}$ 24,082
ZnS: Mn^{2+} 24,077
Magnetic Tape Memory Units, High Bit Packing on 24,810
Magnetic Transitions, Antiferromagnetic-to-Ferromagnetic 24,102
Magnetic Transitions in:
$CoCl_2$-$6H_2O$ 24,103
DyAlG 24,101
Gd 23,966
Magnetization of:
Co, Pressure Effects on 24,150
$CrBr_3$ 24,142
Cupron 24,160
Dy 24,087
Er 24,087
Fe, Aftereffect in 24,156
Fe-Ni 24,163
Ferromagnetic Films 24,146, 24,148
Ferromagnets,
Defect Effects on 24,151
Saturation 24,154
Films 24,213
Garnets, Saturation 24,153
Gd: 24,078, 24,162
Garnet 24,161
Ho 24,087
Mg-Fe Ferrite 24,157
$MnFe_2O_4$ 24,155
MnO 24,158
Mo Permalloy, Work-Anneal Dependence of 24,159
Nb-Zr Superconductors 24,028
Ni-Fe Films 24,203
Magnetization of: (Cont'd)
NiO 24,158
Permalloy 24,159
Y Ferrogarnets 24,174
YIG (Ion Substituted), Spontaneous 24,167
Magnetization Curling in Ferromagnetic Films 24,17
Magnetization Reversal in:
Co-Ni-P Films 24,176
Ferromagnetic Films 24,147
Ferromagnetics 24,175
Ni Tapes 24,177
Permalloy Films 24,178
YIG 24,179
Magnetization Ripple in Ferromagnetic Films 24,17
Magnetoacoustic Attenuation in Bi 24,229
Magnetoacoustic Effect in Mo 24,227
Magnetoacoustic Resonance in Li Ferrite 24,228
Magnetoacoustic Waves in Zn_2Y 24,230
Magnetoconductivity of Organic Semiconductors 23,938
Magnetoelastic Coupling in Ni Ferrite 24,109
Magnetoelastic Waves in YIG 24,108
Magneto-Optic Effect in MnBi Films 24,452
Magnetoplumbite, Magnetostatic Energy of 24,226
Magnetoresistivity, High Field 24,037
Magnetoresistivity of:
$(Ag_2Te)_{0.41}$-$(Sb_2Te_3)_{0.59}$ 23,781
Bi,
Hole Ellipsoids in 24,042
Oscillatory 24,039, 24,041
Self- 24,043
Bi-Sb, Temperature Variation of 24,045
CrI_2, Temperature Dependence of 24,083
Ge 24,044
Graphite 23,847
GaSb, Oscillatory 24,048
In Plates 24,046
InSb, Oscillations in 24,000
InSb Corbino Disks 24,047
PbS, Oscillatory 24,040
$PtSb_2$ 24,049
Rh-Fe, Temperature Dependence of 23,969
ZnSb 23,939
Magnetostatic Energy of Magnetoplumbite 24,226
Magnetostriction of:
Dy 24,107
DyIG 24,107
Ferromagnets 24,165
GdIG 24,107
Mn-Co-Fe Oxides 24,110
Magnetothermal Oscillations in Bi 24,505
Manganese, NMR in 24,302
Manganese in SnO_2, Paramagnetic Resonance of 24,291
Manganese^{2+} in:
MgO, Paramagnetic Resonance of 24,292
$Zn_2P_2O_7$, Paramagnetic Resonance of 24,284
Manganese^{55} in:
$KMnF_3$, NMR of 24,254
MnF_2, NMR of 24,252
$RbMnF_3$, NMR of 24,253
Manganese Bismuth Films,
Ferromagnetic Resonance in 24,452
Magneto-Optic Effect in 24,452
Manganese Carbonate,
Antiferromagnetic:
Nuclear Double Resonance in 24,255
Resonance in 24,250
Ferromagnetic Resonance Linewidth of 24,217
Transmission in 24,250
Manganese-Cobalt-Iron Oxides, Piezomagnetism in 24,110
Manganese-Copper,
Antiferromagnetic Transitions in 24,246
Specific Heat of 24,246
Manganese Ferrite,
Ferromagnetic:
Resonance in 24,218
Resonance Linewidth in 24,219

anganese Ferrite, (Cont'd)
Magnetization of 24,155
Spin-Lattice Relaxation in 24,218, 24,219
Ultrasonic:
Attenuation in 24,534
Wave Velocity in 24,534
anganese Fluoride,
Absorption in 24,339
Antiferromagnetic Spin Waves in 24,240
anganese Iron Ferrites, Ferromagnetic Resonance in 24,204
anganese Mercury,
Preparation of 24,243
Susceptibility of 24,243
anganese Oxide,
Antiferromagnetic Resonance in 24,251
Growth of 23,800
Magnetization of 24,158
Reflection from 24,440
anganese Tin, Nuclear Magnetic Resonance in 24,225
anganese Yttrium Oxide ($MnYO_3$),
Ferromagnetic 24,096
Magnetic Structure of 24,096
anganous Fluoride,
Antiferromagnetic Resonance Line Width of 24,249
NMR of Mn^{55} in 24,252
artensitic Transformation in Co Whiskers 23,795
aser - See Also Laser
aser Applications in Communications Systems 24,788
asers,
Amplitude Variations in 24,616
Applications of 24,615
Introduction to 24,614
Phonon 24,618
Properties of 24,615
Raman 24,618
Ruby 24,617, 24,788
Traveling Wave 24,617, 24,788
lass Spectrometers 24,850
lechanical Energy Flow in Crystals, Theory of 24,506
ledical Electronics; Laser Applications in 24,854
lemory Units,
Card 24,812
Magnetic:
Core 24,811
Film 24,806, 24,807, 24,808
Tape 24,810
Three-State 24,813
Tunnel Diode 24,813
lercury Cadmium Telluride,
Absorption in 24,334
Reflectivity of 24,334
lercury Telluride,
Absorption in 24,334
Reflectivity of 24,334
Thermal Expansion of 24,491
lelting of Ce 23,719
letal Film Transistors 24,596
letal Oxide Film Transistors 24,597
letal Oxides, Conduction in 23,982
letal Working, Laser Applications in 24,853
letallic Systems, Stacking Faults in 23,688
letals,
Acoustic Wave Damping in 24,538
Desorption from 23,814
Electronic Structure of 23,870
Equation of State for: 23,520
fcc 23,521
Helicon Waves in 24,232
Helicon-Phonon Interactions in 24,231
Magnetic States in 24,091
Nernst-Ettingshausen Effect in Ferromagnetic 24,501, 24,502
Optical Constant Measuring Techniques for 24,432
Specific Heat of 24,456
Thermal EMF of 24,496
Metals, (Cont'd)
Thermoelectric Properties of Ferromagnetic 24,497
Ultrasonic Wave Damping in 24,538
Yield Strength of 24,529
Mica, Absorption in 24,352
Mica Filters for Lasers 24,675
Microcircuits 24,691
Microcircuits,
Computer Logic 24,793
Design of 24,688, 24,690, 24,694
Inductors for 24,695
Reliability of 24,692
Semiconductors in 24,697
Technology of 24,689
Microcircuits for Radar Systems 24,693
Microelectronics, Preparation of Films for 23,782
Microminiature Diodes 24,575
Microstrains in Nb 23,712
Microwave Absorption in PbS, Electric Field Effects in 24,357
Microwave Amplifiers 24,715
Microwave Conductivity of Si 23,956
Microwave Power Meters 24,837
Miniaturization, Semiconductors in 24,697
Minority Carrier Storage in Transistors 24,582
Miscibility Gap in:
$CaO-SiO_2-Cr_2O_3$ 23,547
Al-Bi-Pb 23,548
Mixers, Tunnel Diode 24,758, 24,759
Mobility in:
CdS, Hall 23,936
Ge, Low Temperature 23,840
InSb, Grain Boundary 23,980
InSb Films 23,942
Nb_2O_5, Electron 23,943
NiO(Li) 23,941
Si, Anisotropy of 23,974
TiO_2, Electron 23,943
UO_2, Hall 23,987
ZnSb 24,323
Zn_3Sb_2, Hole 24,075
Mobility of Polarons 23,896
Mobility Ratio of $CrSi_2$ 23,993
Modulation Techniques for Lasers 24,650
Modulators,
Amplitude 24,755, 24,756
Electro-Optic 24,677
Laser 24,676, 24,677, 24,678
Optical 24,611, 24,612, 24,613
Pulse 24,756, 24,757
Molecular Crystals, Exciton Diffusion in 23,948
Molten Zones, Shape of 23,762
Molybdenum,
Desorption of F from 23,816
Fermi Surface of 23,854, 24,227
Galvanomagnetic Properties of 23,957
Magnetoacoustic Effect in 24,227
Optical Constants of 24,432
Susceptibility of 24,259
Ultrasonic Attenuation in 24,540
Molybdenum Filaments, Growth of 23,796
Molybdenum-Iron, Growth of 23,790
Molybdenum-Niobium-Iron, Resistivity of 23,996
Molybdenum Permalloy,
Magnetic Properties of 24,118, 24,112
Magnetization of 24,149
Molybdenum-Permalloy Films, Magnetic Properties of 24,117
Molybdenum-Rhenium-Iron, Resistivity of 23,996
Molybdenum-Technetium, Susceptibility of 24,080
Monostable Multivibrators 24,741
Mössbauer Effect 24,398
Mössbauer Effect in:
Be, Fe^{57} 24,400
Co Ferrite 24,261
Cu, Fe^{57} 24,400
Ni Ferrite 24,261
Pt, Fe^{57} 24,400
Sr Ferrite 24,399
W, Fe^{57} 24,400
Motor Controls 24,829, 24,830, 24,831, 24,832
Mott Excitons, Zeeman and Stark Effects of 23,919
Multipliers,
Frequency 24,760, 24,761
Pulse 24,757
Multivibrator Switching Circuits 24,753
Multivibrators 24,736, 24,737, 24,753
Multivibrators,
Astable 24,739, 24,740
Free-Running 24,738
Monostable 24,741

N

Naphthalene Derivative, Crystal Structure of 23,576
Narrow Base Diodes, Switching Times of 24,559
Negative Impedance Converters 24,768
Negative Resistance of Tunnel Diodes 24,565
Negative Resistance Diodes, Bonded 24,561
Neodymium, Magnetic Structure of 24,094
Neodymium in $CaWO_4$, Paramagnetic Resonance of 24,297
Neodymium Ethyl Sulfate, Paramagnetic Resonance Absorption in 24,279
Nernst-Ettingshausen Effect in:
Ferromagnetic Metals 24,501, 24,502
Ge 24,504
Networks,
Analysis of 24,680
Design of 24,686
Flow Graph Techniques for 24,681
Reliability Functions of 24,687
Synthesis of 24,682, 24,683, 24,684
Total Function for 24,679
Neutron Damage in Si 23,615
Neutron Diffraction of Moving Lattices 23,564
Nickel,
Diffusion of Cr in 23,748
Energy Band Structure of 23,839
Ferromagnetic Resonance Linewidth in 24,216
Nernst-Ettingshausen Effect in 24,502
Solubility of C in 23,534
Ultrasonic:
Attenuation in 24,534
Wave Velocity in 24,534
Nickel in MgO, Diffusion of 23,746
Nickel Tapes, Magnetization Reversal in 24,177
Nickel Bromide, Proton Resonance in 24,247
Nickel Carbide, Formation of 23,534
Nickel Chloride, Proton Resonance in 24,247
Nickel-Cobalt Ferrites, Magnetic Anisotropy of 24,184
Nickel-Copper, Elastic Constants of 24,518
Nickel Ferrite,
Ferromagnetic Resonance Line Width in 24,220
Magnetoelastic Coupling in 24,109
Mössbauer Effect in 24,261
Superparamagnetism in 24,261
Nickel Ferrite Films, Growth of 23,798
Nickel Fluoride,
Antiferromagnetic Resonance in 24,250
Ferromagnetic Resonance Linewidth of 24,217
Transmission in 24,250
Nickel Hydride, Resistivity of 23,968
Nickel-Iron - See Also Permalloy
Nickel-Iron,
Elastic Constants of 24,518
Magnetic:
Anisotropy in 24,182
Ordering in 24,182
Nickel-Iron Films,
Ferromagnetic Resonance in 24,203
Magnetic:
Anisotropy of 24,183
Domain:
Structure in 24,192
Wall Creep in 24,196
Magnetization of 24,203
Nickel-Iron-Chromium Films,
Magnetic Properties of 24,115
Preparation of 24,115

Nickel-Iron Ferrites, Magnetic Anisotropy in 24,185
Nickel Oxide,
  Antiferromagnetic Resonance in 24,251
  Growth of 23,800
  Magnetization of 24,158
  Reflection from 24,440
  Twin Walls in 23,709
Nickel Oxide (Li),
  Conductivity of 23,941
  Hall Effect in 23,941
  Mobility of 23,941
  Thermoelectric Power of 23,941
Nickel Superalloys, Eutectic Formation in 23,537
Nickel-Zinc Ferrites, Permeability of 24,169
Niobium,
  Debye Temperature of 24,030
  Dislocation Relaxation in 24,555, 24,556
  Internal Friction in 24,553, 24,554, 24,555 24,556
  Microstrains in 23,712
  Optical Constants of 24,432
  Phonon Attenuation in 24,030
  Snoek Phenomenon in 24,554
Niobium Foils,
  Dislocation Configurations in 23,711
  Interstitials in 23,711
  Twinning in 23,711
Niobium Superconducting Films,
  Critical Temperature of 24,011
  Preparation of 24,011
  Transistions in 24,013
  Tunneling in 24,011
Niobium Superconductors,
  Energy Gap of 24,030
  Specific Heat of 24,465
  Superconducting-to-Normal Attenuation in 24,030
Niobium Carbide,
  Crystal Structure of 23,590
  Free Energy of Formation of 23,527
  Plasticity of 24,520
  Preparation of 23,590
Niobium Oxide, Mobility of Electrons in 23,943
Niobium Oxide Films, Crystal Structure of 23,612
Niobium Oxide Tungstate ($Nb_2O_5 \cdot 3WO_3$), Crystal Structure of 23,594
Niobium Pentoxide-Tantalum Pentoxide, Phase Diagram of 23,544
Niobium Tin (Nb_3Sn) Superconductors, Transition Temperature of 24,022
Niobium-Molybdenum-Zirconium, Phase Diagrams of 23,540
Niobium-Rhenium, Crystal Structure of 23,589
Niobium-Tantalum Superconductors, Transitions in 24,017
Niobium-Tungsten-Zirconium, Phase Diagrams of 23,540
Niobium-Zirconium Superconductors,
  Magnetization of 24,028
  Properties of 24,033
  Transition Temperature of 24,022
Noise in:
  Avalanche Diodes 24,571
  Lasers 24,640, 24,641
  Parametric Amplifiers 24,723
  Semiconductor Devices 24,706
  Transistor Circuits 24,706
  Transistors, 1/f 24,585
Noise Generators, Avalanche Diode 24,571
Nuclear Magnetic Relaxation, Calculations on 24,306
Nuclear Magnetic Relaxation in:
  InTe 24,312
  La 24,311
  Sc 24,311
Nuclear Magnetic Resonance,
  Effect of Electric Field on 24,301
  Kronig-Kramers Relations in 24,300
Nuclear Magnetic Resonance in:
  Beryl, Be^9 24,300
  He^3 (Solid) 24,303
  Mn_xSn 24,225
  $PuAl_2$ 24,304
Nuclear Magnetic Resonance of:
  Be^9 in Beryl 24,300
  Mn^{55} in:
    $KMnF_3$ 24,254
    MnF_2 24,252
    $RbMnF_3$ 24,253
Nuclear Magnetic Resonance Line, Second Moment of 24,307
Nuclear Quadrupole Coupling in:
  $AlCl_3$ 23,877
  $LiAl_5O_8$ 23,878
  Rare Earth Iron Garnets 23,876
Nuclear Quadrupole Interactions in:
  BeO 23,874
  Rare Earth Ions 23,875
Nuclear Quadrupole Measurement of $CrCl_3$ 23,579
Nuclear Quadrupole Resonance, Low Temperature Measurement of 23,873
Nuclear Spin Relaxation 24,308
Nuclear Spin-Lattice Relaxation 24,310
Nuclear Spin-Spin Relaxation 24,309

O

Operational Amplifiers 24,173, 24,727, 24,817
Optical Constants of:
  Al Films 24,328
  In Films 24,328
  Metals, Measurement of 24,432
  Mo 24,432
  Nb 24,432
  PbS 24,431
  W 24,432
Optical Demodulators 24,610
Optical Filters for Lasers 24,673, 24,674, 24,675
Optical Logic, Laser 24,792
Optical Maser - See Laser
Optical Modulation $(NH_4)_2Mn_2(SO_4)_3$ 24,453
Optical Modulation in:
  Ge 24,454, 24,455
  $(NH_4)_2Cd_2(SO_4)_3$ 24,453
Optical Modulators 24,447, 24,611, 24,613
Optical Modulators,
  KDP 24,612
  Lasers 24,676, 24,677
  Strain Effects in 24,612
Optical Properties of InSb Layers 24,034
Optical Transitions in:
  Diamond 24,322
  Semiconductors 24,320, 24,321
  ZnSb 24,323
Optical States in Semiconductors 24,321
Order, Long-Range Interactions in 23,555
Order in Au-Pd 23,557
Order-Disorder Reactions in Zr Films 23,806
Order-Disorder Transitions:
  in $CaO-Y_2O_3-ZrO_2$ 23,989
  of ZrO-CaO 23,988
Ordered Surface Structures 23,813
Ordering in Cu_3Au, Vacancy Effects on 23,556
Organic Semiconductors,
  Conductivity of 23,938
  Hall Coefficient of 23,938
  Magnetoconductivity of 23,938
  Photoconductivity of 24,427
  Thermal Conductivity of 23,938
  Thermoelectric Power of 23,938
  Transport in 23,938
Orientation,
  Goniometer Measurement of 23,823
  Laué Method of 23,825
  Measurement of 23,824
  Quantitative Determination of 23,822
Orthoclase, Thermoluminescence of 24,387
Orthoferrites,
  Magnetic Resonance in 24,207
  Susceptibility of 24,207
Oscillators,
  Crystal 24,734
  Electron Spin 24,748
  Feedback 24,769
  Paramagnetic 24,748
  Phase Shift 24,742
  Pierce 24,769
  Thin Film 24,747
  Tunnel Diode 24,745, 24,746
  Voltage-Controlled 24,735
  Wien Bridge 24,743, 24,744
Oscilloscope Preamplifiers 24,729
Osmium - Arsenopyrite Type Semiconductors 23,8
Osmium-Iridium, Phase Diagram of 23,542
Oxide Crystals, Growth of 23,800
Oxide Phosphors, Electroluminescence of 24,382
Oxidation of Al 23,570
Oxidation of Zr 23,808, 23,809
Oxidation Meters 23,811
Oxygen in BeO, Diffusion of 23,745
Oxygen on Diamond, Adsorption of 23,572

P

Palladium, Galvanomagnetic Properties of 23,95
Palladium-Deuterium, Resistivity of 23,991
Paramagnetic $Eu_{0.5}Gd_{1.6}Se_{2.9}$
Paramagnetic Relaxation in:
  Al_2O_3, Fe^{3+} 24,271
  Al_2O_3, Ti^{3+} 24,273
  CaF_2, Gd^{3r} 24,278
  $K_3Co(CN)_6$ 24,277
  $K_3Co(CN)_6$, Fe^{3+} 24,275
  $RbAl(SO_4)_2 \cdot 12H_2O$, Fe^{3+} 24,275
  TiO_2, Fe^{3+} 24,275
  TmAl, Fe^{3+} 24,274
  TmGa, Fe^{3+} 24,274
Paramagnetic Relaxation of:
  Fe^{3+} in:
    Al_2O_3 24,271
    $K_3Co(CN)_6$, Spin-Lattice 24,275
    $RbAl(SO_4)_2 \cdot 12H_2O$, Spin-Lattice 24,275
    TiO_2, Spin-Lattice 24,275
    TmAl, Spin-Lattice 24,274
    TmGa, Spin-Lattice 24,274
  Gd^{3+} in CaF_2 24,278
  Ti^{3+} in Al_2O_3 24,273
Paramagnetic Resonance, Hyperfine Transitions in 24,263
Paramagnetic Resonance in:
  Al_2O_3, V^{3+} 24,285
  Al_2SiO_5, Cr^{3+} 24,288
  CaF_2,
    Fe^{3+} 24,293
    Gd^{3+} 24,298
  CaO, Fe^{2+} 24,294
  $CaWO_4$,
    Cr^{4+} 24,289
    Nd^{3+} 24,297
  $CuK_2(SO_4)_2 \cdot 6H_2O$ 24,264
  Diamond 23,574
  Dy Ethyl Sulfate, Gd 24,299
  EuO 24,205
  Ge, Donor 24,267
  GeO_2, V 24,286
  K_3 (Co, Fe) $(CN)_6$, Fe^{3+} 24,296
  MgO,
    Fe^{2+} 24,295
    Mn^{2+} 24,292
    V^{2+} 24,287
  $NaNO_2$ 24,282
  $PbNO_3$ 24,281
  Quartz, Color Center 24,266
  SnO_2, Mn 24,291
  ZnO, Iron Group Impurity 24,283
  $Zn_2P_2O_7$,
    Cu^{2+} 24,284
    Mn^{2+} 24,284

Paramagnetic Resonance in: (Cont'd)
ZnS, Iron Group Impurity 24,283
ZnSe, Cr^{+} 24,290
ZnTe, Cr^{+} 24,290
Paramagnetic Resonance of:
Color Centers in Quartz 24,266
Cr^{+} in:
ZnSe 24,290
ZnTe 24,290
Cr^{3+} in Al_2SiO_5 24,288
Cr^{4+} in $CaWO_4$ 24,289
Cu^{2+} in $Zn_2P_2O_7$ 24,284
Donors in Ge 24,267
Fe^{2+} in:
CaO 24,294
MgO 24,295
Fe^{3+} in:
CaF_2 24,293
$K_3(Co,Fe)(CN)_6$ 24,296
Gd in Dy Ethyl Sulfate 24,299
Gd^{3+} in CaF_2 24,298
Iron Group Impurities in:
ZnO 24,283
ZnS 24,283
Mn in SnO_2 24,291
Mn^{2+} in:
MgO 24,292
$Zn_2P_2O_7$ 24,284
Nd^{3+} in $CaWO_4$ 24,297
V in GeO_2 24,286
V^{2+} in MgO 24,287
V^{3+} in Al_2O_3 24,285
Paramagnetic Resonance Absorption:
in Al_2O_3 24,270
in Nd Ethyl Sulfate 24,279
of Fe^{3+} in Calcite 24,280
Paramagnetic Resonance Line Broadening in:
$K_3Co(CN)_6$ 24,276
$RbAl(So_4)_2 \cdot 12H_2O$ 24,276
Paramagnetic Resonance Line Shapes in Al_2O_3, Cr 24,272
Paramagnetic Resonance Line Width, Broadening of 24,268
Paramagnetic Resonance Spectrometers 24,264
Paramagnetic Susceptibility,
Defect Effects on 24,259
Measurement of 24,076
Paramagnetic Susceptibility 24,259
Paramagnetic Susceptibility of:
Diamond 24,258
Eu_2O_3 24,257
Ge 24,258
Mo 24,259
Pt 24,259
Si 24,258
Sn 24,258
Paramagnetism, Parasitic Defect Induced 24,256
Parametric Amplifiers 24,715, 24,724, 24,725
Parametric Amplifiers,
Broad-Banding Theory of 24,720
Gain-Bandwidth of 24,721
K-Band 24,717
Noise in 24,723
Non-Reciprocal 24,719
Nonlinear Immittance 24,718
Stabilization of 24,722
X-Band 24,716
Parametric Frequency Converters 24,762
Paramagnetic Oscillators 24,748
Partial Pressure of GeTe 23,528
Particle Detectors, Junction 24,845
Pectolite, Thermoluminescence of 24,387
Permalloy - See Also Nickel-Iron
Permalloy,
Ferromagnetic Resonance Linewidth in 24,216
Magnetization of 24,159
Permalloy Films,
Magnetic:
Order 24,092
Properties of 24,113, 24,116
Permalloy Films, (Cont'd)
Magnetization Reversal in 24,178
Spin-Waves in 24,144
Permeability of:
Ferromagnets 24,165
Ni-Zn Ferrites 24,169
YIG 24,170
Permittivity - See Also Dielectric Constant
Permittivity,
Measurement of Complex 23,885
Theory of 23,881
Permittivity of $BaTiO_3$, Temperature Dependence of 23,892
Phase Diagram of:
Al-Mo 23,541
Ba 23,546
Ce 23,545
Chlorides 23,538
Cu-Zr 23,543
InSb 23,549
Nb-Mo-Zr 23,540
Nb-W-Zr 23,540
Nb_2O_5-Ta_2O_5 23,544
Os-Ir 23,542
U-Al-Fe 23,539
W-C 23,550
Phase Shift Oscillators 24,742
Phase Transitions, Close-Packed to Nonclose-Packed 23,551
Phase Transitions in:
Austenite Foils 23,552
CaO-Y_2O_3-ZrO_2 23,989
CdS 23,577
CdTe 23,577
$CrCl_3$ 23,579
Ferrite Foils 23,552
GaP 23,577
Group:
I-VIII Compounds 23,577
II-VI Compounds 23,577
III-V Compounds 23,577
H_2S (Solid) 23,580
InSb 23,549
Sb 23,554
Sn 23,553
W-C 23,550
Yb 23,551, 24,527
ZnS 23,577
ZrO-CaO 23,988
Phonon Attenuation in Nb 24,030
Phonon Distribution, Neutron Scattering Determination of 23,867
Phonon Drag in Si 23,869
Phonon Masers 24,618
Phonon Processes in $SrTiO_3$, Multi- 24,341
Phonon Scattering in:
CdS 23,868
CdTe 23,868
GaAs 23,868
GaSb 23,868
InSb 23,868
Phonon-Helicon Interactions in Metals 24,231
Phosphor Pumping of Lasers 24,647
Phosphors,
Electroluminescence of:
Oxide 24,382
ZnO 24,374
ZnS 24,374
ZnS:Cu 24,377, 24,378
ZnS:Cu:Al 24,379
Zn(S:Se):Cu 24,376
Electroluminescent Deterioration in ZnS:Cu:Halogen 24,380
Fluorescence of:
CdSe 24,393
Rare Earth Oxide 24,394
Luminescence of:
ZnS:Cu 24,406
ZnS:Cu:Cl 24,405
Photoluminescence of 24,390
Phosphors-Luminors, Electroluminescence of Zn-Cd-S-Se 24,375
Phosphorus (White), Creep in 24,525
Phosphorus in Si, Diffusion of 23,736
Phosphorus Oxides, Heat of Formation of 23,523
Photoconductive Cells,
Characteristics of 24,603
Recognition Phenomenon in 24,602
Photoconductivity of:
Azulene 24,428
CdS: 24,064, 24,415
Films 24,413
CdS:I:Cu, Gain of 24,414
CdSe 24,415
Cu_2O 24,425
GaAs 24,421
GaP 24,422
GaSb 24,423
GaSe 24,420
Ge 23,929, 24,409, 24,410
InS_3 23,834
KBr Films 24,426
KCl Films 24,426
Organic Semiconductors 24,427
RbI Films 24,426
RbCl Films 24,426
S, Pressure Effects on 24,408
Si 23,926
TlSe, Temperature Dependence of 24,418
ZnO-Eosin Films 24,424
ZnSe 24,419
Photocurrent in:
CdS, Saturation of 24,411, 24,412
CdSe, Pulses of 24,417
Superconductors 24,407
Photodiodes,
Laser Beat Detecting 24,606
Point-Contact 24,606
Storage in 24,604, 24,605
Photoelectric Detectors, Communication Channel Model of 24,601
Photoelasticity in Ge 24,507
Photoemission from:
Au Films 24,063
CdS 24,064
Cu Films 24,063
Ge Films 24,063
Photo-Field Effect Transistors 24,608, 24,609
Photointegrating Meters 24,840
Photo-Ionization in Cd (S:Se) 24,416
Photoluminescence of:
InAs 24,391
SiC 24,362
ZnS 24,390
Photomagnetic Effect in:
Ge 24,429
InSb 24,430
Photometers for Lasers 24,670
Photon Avalanches from Lasers 24,636
Phototransistor Temperature Controllers 24,833
Phototransistors, Response of 24,607
Photovoltaic Cells, Characteristics of 24,603
Piezoelectric $Pb(Zr-Ti)O_3$ 23,915
Piezoelectrics,
Acoustic Wave Amplification 24,549
Ultrasonic:
Propagation in 24,536
Wave Amplification in 24,549
Piezomagnetic Mn-Co-Fe Oxides 24,110
Piezoresistivity of:
Alloys, Anelastic 23,972
CdS 23,979
GaAs 23,976
GaSb 23,977
Ge: 23,840
Films 23,975
PbS 23,978
PbSe 23,978
PbTe 23,978
Si 23,974

Planar Diodes, Current-Voltage Relation in Space Charge 24,560
Planar Transistors 24,578, 24,599
Plastic Deformation of:
  Ge 24,522
  Polymer Crystals 23,658
Plastic Flow in:
  Alkali Halides, Purity Dependence of 24,521
  NaCl, Purity Dependence of 24,521
Plastic Flow Relaxation in:
  Quartz 24,523
  Silica 24,523
Plasticity of:
  NbC 24,520
  TiC 24,520
  ZrC 24,520
Platinum,
  Dislocation Peaks in 24,551
  Dislocations in 23,651
  Internal Friction in 24,551
  Mössbauer Effect for Fe^{57} in 24,400
  Susceptibility of 24,259
Platinum Wires, Resistivity of 23,985
Platinum-Aluminum Films, Crystal Structure of 23,613
Platinum Antimonide,
  Magnetoresistivity of 24,049
  Valence Band Structure of 24,049
Plutonium,
  Fluorescence of 24,392
  Specific Heat of 24,466
Plutonium Aluminide ($PuAl_2$), NMR in 24,304
Point-Contact Photodiodes 24,606
Polarization of:
  Alkali Halides, High Temperature 23,908
  Ferroelectric Ceramics 23,910
  Ferroelectrics 23,909
  KH_2PO_4, Reversal of 23,907
  Rochelle Salt, Spontaneous 23,905
  TGS, Reversal of 23,906
Polarons, Mobility of 23,896
Polishing of YIG Spheres 23,826
Polymer Crystals,
  Dislocations in 23,658
  Plastic Deformation of 23,658
Polymers, Crystallization of 23,760, 23,761
Polymorphic Transformation in:
  PbS 23,978
  PbSe 23,978
  PbTe 23,978
Polymorphic Types of $FeNbO_4$ 23,597
Polymorphs of Cu_5FeS_4 23,582
Polytype of CdI 23,578
Porous Media, Thermal Conductivity of 24,476
Positrons in:
  Alkali Halides, Annihilation of 23,871
  Na, Annihilation of 23,850
  Rare Earth Metals, Annihilation of 23,849
Potassium,
  Conductivity of 23,973
  Elastic Constants of 24,515, 24,459
  Fermi Surfaces of 23,870
  Growth of 23,789
  Heat Capacity of 24,460
  Specific Heat of 24,459
Potassium from W, Desorption of 23,815
Potassium Bromide,
  Absorption in 23,914
  Color:
    Center Generation in 23,637
    Centers in 23,642
  Defects in 23,914
  Dielectric Relaxation in 23,914
  F-Center Generation in 23,637
  Gruneisen Constant of 24,474
  Specific Heat of 24,474
  Thermal Expansion of 24,474
  Thermoluminescence of 24,385
Potassium Bromide Films,
  Photoconductivity of 24,426
  Secondary Electron Emission from 24,062
Potassium Chloride,
  Absorption in 24,345
  Color:
    Center Generation in 23,637
    Centers in 23,643, 23,644, 23,645, 23,646
  Compressibility of 24,474
  Electron Diffraction Streak Patterns in 23,563
  F-Center Generation in 23,637
  Gruneisen Constant of 24,474
  Ionic Conductivity of 23,990
  Secondary Electron Emission from 24,061
  Specific Heat of 24,474
  Thermal Expansion of 24,474
  Thermoluminescence of 24,385
Potassium Chloride:Te, Absorption in 24,345
Potassium Chloride Films, Photoconductivity of 24,426
Potassium Cobaltocyanide, Paramagnetic:
  Relaxation in 24,277
  Resonance Line Broadening in 24,276
  Spin-Lattice Relaxation of Fe^{3+} in 24,275
Potassium (Cobalt-Iron) Cyanide, Paramagnetic Relaxation of Fe^{3+} in 24,296
Potassium Dihydrogen Phosphate,
  Polarization Reversal in 23,906
  Thermoluminescence of 24,386
Potassium Dihydrogen Phosphide Optical Modulators 24,612
Potassium Iodide, Color Center Formation in 23,641
Potassium Iodide:Tl, Absorption in 24,356
Potassium Manganese Fluoride, Specific Heat of 24,473
Potassium Manganese Fluoride (KM_2F_3), NMR of Mn^{55} in 24,254
Potassium Nickel Fluoride (K_2NiF_4), Magnetic Stacking Faults in 24,245
Powders, Dielectric Constant of S 23,894
Power Amplifiers 23,731
Power Meters, Microwave 24,837
Power Regualtors 24,824
Power Supplies,
  DC 24,827
  Laser 24,678
  Short Circuit Protected 24,828
Power Transistors, Life Tests on Ge 24,576
Praesodymium, Compression of 24,527
Preamplifiers,
  FM 24,778
  Minimum Detectable Signal of 24,730
  Oscilloscope 24,729
Precipitates in:
  MgO 23,756
  Si 23,755
Precipitation, Theory of: 23,751
  Cellular 23,752
Precipitation in:
  Al-Zn, Irradiation Effects on 23,753
  Fe, C 23,971
  Fe, Nitride 23,754
  UC Films, UC_2 23,757
Preparation of - See Also Growth of
Preparation of:
  $AgFeO_2$ 23,596
  $(Ag_2Te)_{0.41}-(Sb_2Te_3)_{0.59}$ 23,781
  $CuS_{1.96}$ 23,581
  Diamonds 23,772
  EuO 24,469
  Ferrites 23,799
  Films 23,769
  GaAs 23,778
  $Ga(As_{1-x}P_x)$ 24,625
  In As_y Sb_{1-y} Films 24,331
  InS_3 23,834
  InTe 23,575
  MnHg 24,243
  Nb:
    Carbides 23,590
    Superconducting Films 24,011
  Ni-Fe-Cr Films 24,115
  PbTe 23,780
  SnTe 23,833
Preparation of: (Cont'd)
  Superconducting Films 23,769
  Ta Superconducting Films 24,011
  UC Films 23,757
  V Superconducting Films 24,011
Proton Resonance in:
  $CoBr_2-6H_2O$ 24,247
  $CoCl_2-6H_2O$ 24,247, 24,103
  $NiBr_2-6H_2O$ 24,247
  $NiCl_2-6H_2O$ 24,247
Pulse Amplifiers 24,728, 24,757, 24,765, 24,77
Pulse Circuits,
  Multivibrator 24,741
  Tunnel Diode 24,849
Pulse Counters 24,764
Pulse Detectors, Laser 24,640
Pulse Discriminators 24,765
Pulse Generators 24,763
Pulse Height Analyzers 24,851
Pulse Height Discriminators 24,766
Pulse Modulators 24,756, 24,757
Pulse Multipliers 24,757
Pumping of Lasers, Phosphor 24,647
Purification of:
  B 23,721
  GaAs 23,778
Purity of Ce, Analysis of 23,719
Pyrolytic Graphite, Galvanomagnetic Properties 24,035
Pyroxenes, Elastic Constants of 24,519

Q

Q-Tuned Ruby Lasers, Spikes in 24,657
Quantum Absorption in:
  Al Films 24,328
  In Films 24,328
Quartz,
  Paramagnetic Resonance of Color Centers in 24,266
  Plastic Flow Relaxation in 24,523
Quartz Granules, Thermal Conductivity of 24,484

R

Radar Systems, Integrated Circuits for 24,693
Radiation, Crystallization of Ge by 23,776
Radiation Detectors,
  AgCl 24,848
  Alpha-Gamma 24,846
  Thermopile 24,839
Radiation from:
  Diamond, Recombination 24,366
  Ge, Recombination 24,367
  PbTe, Recombination 24,371
Radiation Ratemeters 24,844
Radium, Fluorescence of 24,392
Raman Effect in F-Centers 24,363
Raman Masers 24,618
Ranging Systems, Laser 24,789, 24,790, 24,79
Rare Earth Ions, Nuclear Quadrupole Interaction in 23,875
Rare Earth-Beryllium (RBe_{13}), Crystal Structure o 23,584
Rare Earth Iron Garnets, Nuclear Quadrupole Coupling Constant of 23,8
Rare Earth Metals, Positron Annihilation in 23,8
Rare Earth Orthoferrites, Curie Temperature of 24,168
Rare Earth Oxide Phosphors, Fluorescence of 24,
Rare Earth-Sodium Molybdenum Scheelites,
  Growth of 23,801
  Susceptibility of 23,801
Ratemeters 24,844
Reactor Temperature Controls 24,852
Receivers, AM 24,777
Recombination - See Also Lifetime
Recombination, Surface 23,930

ecombination in:
Ge,
Cd Impurity Effects on 23,925
Cross Sections of 23,929
Si 23,926
ecombination Centers in Ge, Annealing of 23,924
ecombination Cross Sections 23,928
ecombination Cross Sections, Electric Field Effects on 23,927
ecombination Emission from CdS 24,332
ecombination Luminescence:
of Alkali Halides 24,373
in GaP Diodes 24,369
ecombination Mechanisms 23,921, 23,922
ecombination Radiation from:
Diamond 24,366
GaP Diodes 24,370
Ge, Magnetic Field Effect on 24,367
PbTe 24,371
ectification in Anodic Films on Al 24,074
ectifiers - See Also Diodes
ectifiers,
Au-TiO_2 24,562
Characteristics of 24,562
eflection from:
Al_2O_3, Ultraviolet 24,442
As 24,435
$BaTiO_3$, Temperature Dependence of 24,441
BeO Ultraviolet 24,442
Bi 24,435
CoO, Infrared 24,440
CdS 24,437, 24,438
CdSe 24,436
Diamond, Ultraviolet 24,322
GeTe 24,435
Group:
IV-VI Compounds 24,435
V Semimetals 24,435
MnO, Infrared 24,440
NiO, Infrared 24,440
Pb-Group VI Compounds 24,435
PbS 24,435
PbSe 24,435
PbTe 24,435
Rough Surfaces 24,433
Sb 24,435
Si 24,329
SiO_2, Ultraviolet 24,442
SnTe 24,435
$SrTiO_3$, Temperature Dependence of 24,441
ZnS 24,438, 24,439
eflectivity, Calculation of 24,325
eflectometers 24,434
efractive Index of:
Al Films 24,328
CdTe 24,445
GaAs 24,444
$InAsySb_{1-y}$ Films 24,331
In Films 24,328
InS_3 24,834
InSb Layers 24,034
PbS 24,431
Semiconductors 24,443
ZnSe 24,445
ZnTe 24,445
Regulators,
Analysis of 24,823
Current 24,825, 24,826
Power 24,824
Relaxation Circuits, Unijunction Transistor 24,709
Remendar, Magnetic Properties of 24,120
Resistivity - See Also Conductivity
Resistivity,
Four Point Probe Measurement of 23,958,23,959
Measurement of 23,955, 23,957, 23,960, 23,958, 23,959
Surface 23,961
Resistivity of:
Ag Whiskers 23,964
$(Ag_2Te)_{0.41}$-$(Sb_2Te_3)_{0.59}$ 23,781
Alloys, Anelastic 23,972
Resistivity of: (Cont'd)
Ba, Temperature-Pressure Dependence of 23,546
$BaTiO_3$ 23,893
$BaZrO_3$ 23,995
Bi,
Grain Size Dependence of 23,981
Nonlinear 23,963
Bi-Sb,
Grain Size Dependence of 23,981
Temperature Variation of 24,045
CdS 23,979
CdSe Films 23,949
CdTe Films 23,950
Co-Ni, Stacking Fault Effects on 23,695
CrI_2, Temperature Dependence of 24,083
$CrSi_2$ 23,993
Cu Whiskers 23,964
Cu-Ni, Stacking Fault Effects on 23,695
Fe 23,971
GaAs 23,976
GaSb 23,977
Ge, Oscillations of 23,999
Ge: 24,044
Films 23,975
Gd 23,966
Graphite, Non Linear 23,963
HgCdTe 24,334
HgTe 24,334
In Plates 24,046
InSb 23,983
InSb, Oscillations in 24,000
Li Ferrite-Chromite, Temperature Dependence 24,264
Mo-Nb-Fe, Anomalies in 23,996
Mo-Re-Fe, Anomalies in 23,996
NiH, Temperature Dependence of 23,968
PbS 23,978
PbSe 23,978
PbTe 23,978
PbTe-SnTe 23,832
Pd-D 23,991
Pt Wires, Recovery of 23,985
Rh, Annealing of 23,984
Rh-Fe, Temperature Dependence of 23,969
Ru 23,967
Semiconductors, Magneto-Concentration Changes in 24,038
Si 23,974
Wires 23,962
Resonators for Lasers, Fabry-Pérot 24,671
Response of Phototransistors 24,607
Reverse Current of:
Diodes, Measurement of 24,558
Tunnel Diodes, Magnetic Field Dependence of 24,567
Rhenium,
de Haas-van Alphen Effect in 24,315
Fermi Surface of 24,315
Galvanomagnetic Properties of 23,957
Text on 23,516
Rhodium,
Defects in 23,984
Resistivity of 23,984
Rhodium-Iron,
Magnetoresistivity of 23,969
Resistivity of 23,969
Ring Counters 24,799
Rochelle Salt,
Dielectric Dispersion in 23,895
Polarization of 23,905
Rolling Texture of Cu 23,689
Root Mean Square Circuits 24,819
Rubidium,
Fermi Surfaces of 23,870
Heat Capacity of 24,460
Rubidium Alum, Paramagnetic:
Resonance Line Broadening in 24,276
Spin-Lattice Relaxation of Fe^{3+} in 24,275
Rubidium Bromide:Na, Absorption in 24,346
Rubidium Chloride:Na, Absorption in 24,346
Rubidium Chloride Films, Photoconductivity of 24,426
Rubidium Iodide Films, Photoconductivity of 24,426
Rubidium Manganese Fluoride, Specific Heat of 24,473
Rubidium Manganese Fluoride ($RbMnF_3$), NMR of Mn^{55} in 24,253
Ruby,
Absorption in 23,718, 24,342
Cathodoluminescence of 24,389
Cr Concentration in 23,718
Growth of 23,800, 24,662
Paramagnetic Resonance:
Absorption in 24,270
Lineshapes of Cr in 24,272
Reflection from 24,442
Ruby Lasers,
Characteristics of 24,662
Gain in 24,617
Ground State Population of 24,646
Oscillations in 24,655, 24,656
Output Parameters of 24,663
Pulse/Amplitude Modulated 24,389
Pumping in 24,649
Resonator for 24,672
Spikes in Q-Tuned 24,657
Spiking in 24,658, 24,649
Stokes Shift in 24,660
Ultrasonic Produced Oscillations in 24,645
Ruby Masers, Gain in 24,617
Ruby Traveling-Wave Masers 24,788
Ruthenium,
Resistivity of 23,967
Thermal Resistivity of 23,967
Ruthenium - Arsenopyrite Type Semiconductors 23,835
Rutile,
Conductivity of 23,986
Dielectric Constant of 23,891
Hall Coefficient of 24,054
Mobility of Electrons in 23,943
Paramagnetic Spin-Lattice Relaxation of Fe^{3+} in 24,275

S

Samarium Iron Garnets, Magnetic Moment of 24,104
Sapphire, Thermal Expansion of 24,486
Saturation Magnetization of Garnets, Short Range Order Effects 24,153
Scalers, Tunnel Diode 24,849
Scandium,
Compression of 24,527
Nuclear Magnetic Relaxation in 24,311
Scandium Cadmium ($ScCd_3$), Crystal Structure of 23,587
Scapolite, Thermoluminescence of 24,387
Scattering, Relaxation in 23,946
Scattering in:
Ge, Electron 23,945
Si, Electron 23,945
Scattering of:
Electrons, Moment Transfer to Impurity Centers in 23,944
Excitons by Dislocations 23,947
Schmitt Trigger Circuits 24,751
Schottky Barriers on CdS 24,070
Schottky Ionization from Excited F-Centers 24,073
Schubnikov-de Haas Effect, Measurement of 24,039
Schubnikov-de Haas Effect in:
Bi 24,039, 24,041
GaSb 24,048
PbS 24,040
Scintillation Counters 24,847
Screw Dislocations, Dilatation Field of 23,679
Second Breakdown in Transistors 24,580
Second Sound in Solids, Dispersion of 24,543
Second Sound Velocity in:
NaCl 24,546
Dielectrics 24,546

Secondary Electron Emission from:
  Au Films 24,063
  Cu Films 24,063
  Ge Films 24,063
  KBr Films 24,062
  KCl 24,061
Seebeck Coefficient of:
  Bi_2Te_3 24,052
  InP 24,481
  PbTe-SnTe 23,832
  $SrTiO_3$ 23,992
Segregation in:
  Crystal Growth, Prediction of 23,759
  Spherulitic Crystallization 23,760, 23,761
Selenium in GaAs, Diffusion of 23,743
Self-Diffusion in BeO, Be 23,727
Semiconductor Devices, Noise in 24,706
Semiconductor Films,
  Growth of 23,765, 23,782
  Preparation of 23,769
Semiconductor Lasers 24,665
Semiconductors,
  Absorption in 24,324, 24,326, 24,343
  Acoustic Wave Velocity in 24,547
  Conduction in 23,952
  Conductivity of 23,951
  Current Instabilities in 23,997
  Energy Gap Transitions in 23,843
  Exchange Interactions in 24,132
  Faraday Rotation in 24,450
  Growth of 23,777
  Hall Effect in Low Mobility 24,050
  Lifetime of 23,843
  Optical:
    States in 24,321
    Transitions in 24,320, 24,321
  Photoconductivity of 24,427
  Refractive Index Near Absorption Edge in 24,443
  Resistivity Changes in 24,038
  Superconductivity in Many-Valley 24,009
  Supersaturation During Growth of 23,775
  Thermomagnetic Coefficients of 24,503
  Transport in 23,934
  Ultrasonic Wave Velocity in 24,547
Semimetals,
  Acoustic Wave Velocity in 24,547
  Current Instabilities in 23,997
  Superconductivity in Many-Valley 24,009
  Ultrasonic Wave Velocity in 24,547
Shapers, Pulse 24,765
Shift Registers 24,801, 24,802, 24,804
Shift Registers,
  Cryotron 24,705
  Feedback 24,803
Shutter Controls 24,836
Silica, Plastic Flow Relaxation in 24,523
Silicon,
  Absorption in 24,329
  Acoustoelectric Effect in n-Type 24,072
  Anodization of 23,810
  Conductivity of 23,956
  Contacts to 24,600
  Crystal Structure of 23,573
  Decoration of 23,820
  Defects in:
    Heat Treated 23,663
    Neutron Irradiated 23,615
  Diffusion of:
    B in 23,735
    P in 23,736
  Dislocation Networks in 23,665
  Dislocations in 23,699, 23,700
  Effective Mass of Electrons in 23,932
  Electron Diffraction Streak Patterns in 23,563
  Energy Levels in 23,974
  Fermi Level of 23,974
  Hall Coefficient of Irradiated 24,051
  Interstitials in 23,631
  Mobility Anisotropy of 23,974
  Phonon Drag in 23,869
  Photoconductivity of 23,926
Silicon, (Cont'd)
  Piezoresistivity of 23,974
  Precipitates in 23,755
  Recombination at Zn Atoms in 23,926
  Reflection from 24,329
  Resistivity of 23,974
  Scattering of Electrons in 23,945
  Stacking Faults in 23,699, 23,700
  Surface States of 23,858
  Susceptibility of 24,258
  Vacancies in 23,631
  Web Growth of 23,777
Silicon:(B, Li), Absorption in 24,350
Silicon Films,
  Doping of 23,723
  Growth of 23,571, 23,782, 23,783, 23,784
  Stacking Faults in 23,701
  Surface Structure of 23,571
Silicon Planar Switching Transistors 24,578
Silicon Symmetrical Transistors, Fabrication and Characteristics of 24,598
Silicon Whiskers, Growth of 23,768
Silicon Bronze, Stacking Faults in 23,702
Silicon Carbide,
  Absorption Edge in 24,362
  Applications of 23,518
  Photoluminescence of 24,362
Silicon Carbide Laser Diodes 24,630
Silicon Dioxide,
  Paramagnetic Resonance of Color Centers in 24,266
  Reflection from 24,442
Silicon Iron, Ferromagnetic Resonance Linewidth in 24,216
Silicon Oxide Films,
  Conductivity of 23,887
  Dielectric Properties of 23,887
Silicon Oxide Precipitates in Si 23,755
Silicon Steels, Magnetic Loss in 24,180
Silver,
  Catalysis by 23,817
  Decoration of Facets on 23,821
  Dislocation Peaks in 24,551
  Equation of State for 23,521
  Facets on 23,821
  Heat Capacity of 23,866
  Internal Friction in 24,551
  Lattice Vibrations in 23,866
  Vacancy Annealing in 23,627
  Young's Modulus of 24,516
Silver in GaAs,
  Diffusion of 23,744
  Solubility of 23,744
Silver Whiskers, Resistivity of 23,964
Silver Antimony Telluride,
  Density of 23,781
  Energy Band Structures of 23,781
  Hall Constant of 23,781
  Magnetoresistivity of 23,781
  Preparation of 23,781
  Resistivity of 23,781
Silver-Antimony-Tellurium, Pb Distribution in 23,536
Silver Chloride,
  Absorption in 24,338
  Dislocation Charge in 23,667
  Internal Friction in 24,557
  Luminescence of 24,338
Silver Chloride Radiation Detectors 24,848
Silver Ferrite,
  Crystal Structure of 23,596
  Preparation of 23,596
Silver Halides, Defects in 23,614
Silver Solid Solutions, Stacking Faults in 23,693
Silver-Tin-Cadmium, Lattice Parameters of 23,608
Simulation Techniques, Analog 24,816
Slip in Cu 23,716
Slip Lines in Cu 23,684
Snoek Phenomenon in Nb 24,554
Sodium,
  Conductivity of 23,973
  Defect-Compressibility Relationships in 23,623
  Defect-Thermal Expansion Relationships in 23,61
  Electronic Structure of 23,850
  Fermi Surface of 23,850, 23,851
  Growth of 23,789
  Positron Annihilation in 23,850
Sodium Chloride,
  Color:
    Center Generation in 23,637
    Centers in 23,640
  Compressibility of 24,474
  Dislocation:
    Boundaries in 23,666
    Distributions in 23,686
    Etching of 23,655
    Generation by X-Rays in 23,664
  Dislocations in 23,659
  Electron Diffraction Streak Patterns in 23,563
  F-Center Generation in 23,637
  Gruneisen Constant of 24,474
  Interstitial Energies in 23,633
  Luminescence of F-Centers in 24,403
  Plastic Flow in 24,521
  Specific Heat of 24,474
  Thermal Expansion of 24,474
  Thermoluminescence of 24,385
Sodium Fluoride, Second Sound Velocity in 24,54
Sodium Iodide:Te, Absorption in 24,356
Sodium Manganese Fluoride, Specific Heat of 24,473
Sodium Niobate, Ferroelectric 23,901
Sodium Nitride, Color Centers in 23,638
Sodium Nitrite,
  Absorption in 24,340, 24,354
  Dielectric:
    Constant of 23,890
    Loss of 23,890
  Paramagnetic Resonance in 24,282
Solar Cells, GaP 23,786
Solders, Specific Heat of 24,464
Solid Solutions of F Ferrites 24,119
Solid Solution System, $BaTiO_3$ 23,806
Solids, Physics of 23,830
Solubility of:
  Ag in GaAs 23,744
  C in Ni 23,534
  CdTe in:
    PbTe 23,535
    SnTe 23,535
  InTe in:
    PbTe 23,535
    SnTe 23,535
  Zn in:
    GaAs 23,740
    GaP 23,740
Solutions of Co_2O_4-Mn_3O_4 23,526
Sparked Contacts, Si 24,600
Specific Heat - See Also Heat Capacity
Specific Heat, Calorimeter for Measuring 24,458
Specific Heat of:
  an Antiferromagnet 24,236
  Crystals with Heavy Impurities 24,457
  Cs 24,462
  CsBr 24,474
  $CsMnF_3$ 24,473
  Cu (Impure) 24,123
  Cu-Co 24,123
  Cu-Fe 24,123
  EuO 24,469
  Heisenberg Ferromagnet 24,138
  K 24,459
  KBr 24,474
  KCl 24,474
  $KMnF_3$ 24,473
  Metals 24,456
  Mg Alloys 24,471
  Mn-Cu 24,246
  NH_4HSO_4, Temperature Dependence of 24,47
  NH_4MnF_3 24,473

pecific Heat of: (Cont'd)
NaCl 24,474
$NaMnF_3$ 24,473
Nb Superconductors 24,465
Pb-Sn Solders 24,464
Pu 24,466
$RbMnF_3$ 24,473
pectrometers 24,850
pin Configuration of Gd 24,078
pin-Lattice Relaxation 24,310
pin-Lattice Relaxation in:
Al_2O_3 24,273
$MnFe_2O_4$ 24,218
Mn Ferrite 24,219
pin Relaxation, Theory of 24,262
pin Resonance, Theory of 24,262
pin Resonance of F_2-Centers in 24,265
pin-Spin Relaxations 24,269
pin Systems, Bloch Equations for 24,137
pin Wave Pumping 24,223
pin Wave Pumping in YIG 24,223
pin Wave Resonance in Films 24,222
pin Waves, Computer Study of 24,140
pin Waves in:
Antiferromagnets 24,241
Co Films 24,144
$CrBr_3$ 24,142
Fe-Ni 24,145
Ferrites, Computer Study of 24,141
Ferromagnetism 24,139
Fe Films 24,144
Heisenberg Ferromagnet 24,138
MnF_2 24,240
Permalloy Films 24,144
pinel, Cathodoluminescence of $MgAl_2O_4$ 24,388
pontaneous Magnetization of YIG (Ion Substituted) 24,167
puttering in Thin Film Preparation, Getter 23,769
puttering of GaSb 23,827
quare Wave Generators 24,736
tabilization of:
Amplifiers, Feedback 24,710
Parametric Amplifiers 24,722
tacking Fault Energy, X-Ray-Electron Techniques for Measuring 23,698
tacking Faults, Growth of Films Without 23,783
tacking Faults in:
Ag Solid Solutions 23,693
Al, Interaction with Dislocations of 23,680
Au, Nucleation of 23,629
Au Foils 23,704
bcc Metals 23,691
Co, NMR-Electron Microscopy Determination of 23,703
Co-Ni 23,695
Cu: 23,689
Films 23,692
Cu-Al 23,696, 23,697
Cu-Ge, Energy of 23,698
Cu-Ni 23,695, 23,696, 23,697
Cu-Ni, Energy of 23,694
Cu Solid Solutions 23,693
fcc:
Alloys 23,687
Metals, Energy of 23,690
K_2NiF_4 Magnetic 24,245
Metallic Systems 23,688
Si: 23,699, 23,700
Films 23,701
Bronze 23,702
SnS_2 23,705
Stannic Oxide, Paramagnetic Resonance of Mn in 24,291
Stimulated Emission from:
$Gd_2O_3:Nd^{3+}$ 24,396
$Y_2O_3:Nd^{3+}$ 24,669
Storage in Photodiodes 24,604, 24,605
Storage Units, Random Access 24,814
Storage Units, Rod 24,809
Strain Hardening in Cu 24,533
Strength of MgO, Irradiation Effects on 24,528
Stress-Strain Relations in Al 24,508
Strontium, Reflection from 24,441
Strontium Ferrite, Mössbauer Effect in 24,399
Strontium Titanate,
Conductivity of 23,992
Energy Band Structure of 23,992
Growth of 23,800
Hall Coefficient of 23,992
Seebeck Coefficient of 23,992
Transmission in 24,341
Strontium Zinc ($SrZn_2$), Crystal Structure of 23,583
Sublattice Magnetization of $MnFe_2O_4$ 24,155
Substrate Holders 23,774
Sulfur, Photoconductivity of 24,408
Sulfur in GaAs, Diffusion of 23,743
Sulfur Powders, Dielectric Constant of 23,894
Superalloys, Ni 23,537
Superconducting:
Cd 24,463
(Ce-Gd) Ru 24,124
Cu 24,463
Ga 24,463
GeTe 24,032
In-Pb, Critical Fields in 24,019
InSb 24,031
La,
Absorption in 24,351
Energy Band Structure of 24,007
Model for 24,007
Nb,
Energy Gap of 24,030
Specific Heat of 24,465
Superconducting-to-Normal Attenuation in 24,030
Nb Films,
Critical Temperature of 24,011
Preparation of 24,011
Transitions in 24,013
Tunneling in 24,011
Nb_3Sn, Transition Temperature of 24,022
Nb-Ta, Transitions in 24,017
Nb-Zr 24,033
Nb-Zr,
Magnetization of 24,028
Transition Temperature of 24,022
Pb-In, Transitions in 24,017
Pb-Pt Films 24,012
Pb-Tl, Critical Field of 24,020
Sn,
Surface Impedance of 24,023, 24,024
Ultrasonic Attenuation in 24,542
Sn-In, Surface Impedance of 24,023
Ta Films,
Critical Temperature 24,011
Preparation of 24,011
Transitions in 24,013
Tunneling in 24,011
U,
Energy Band Structure of 24,007
Model for 24,007
V Films,
Critical Temperature of 24,011
Preparation of 24,011
Tunneling in 24,011
V_3Ge Films, Transitions in V_3Ge 24,013
Zr, Transition Temperature in 24,021
Superconducting Films,
Energy:
Density in 24,014
Gap of 24,015
Preparation of 23,769
Superconducting-to-Normal Attenuation in Nb Superconductors 24,030
Superconductivity,
BCS:
Integral Equations on 24,003
Interactions in 24,001
Conditions for 24,002
Field-Theoretical Methods in 24,008
Ginzburg-Landau Equations on 24,004
Impurity Effects on 24,010
Superconductivity, (Cont'd)
Model of 24,006
Time Effects in 24,016
Superconductivity in Many-Valley:
Semiconductors 24,009
Semimetals 24,009
Superconductors,
Field Distribution in 24,025
Flux Jump in 24,027
Magnetic Flux in 24,026
Photocurrents in 24,407
Ultrasonic Attenuation in 24,511
Superconductors (II),
Critical Current of 24,018
Ginzburg-Landau Equations for 24,005
Susceptibility of 24,029
Superparamagnetism in:
Co Ferrite 24,261
Magnetic Dilute Systems 24,260
Ni Ferrite 24,261
Supersaturation in Semiconductors During Growth 23,775
Surface Barrier of Au-Si 24,069
Surface Barrier Diodes, Surface Impurity Effects on 24,563
Surface Controlled Devices, Applications of 24,703
Surface Diffusion of Ge on Cu 23,731
Surface Impedance of:
Sn Superconductors 24,023, 24,024
Sn-In Superconductors 24,023
Surface Properties of CdS 24,070
Surface Recombination 23,930
Surface Resistivity, Measurement of 23,961
Surface States of:
GaAs 23,857
Group III-V Compounds 23,856
Ge 23,858
Si 23,858
Surface Structure,
Ordered 23,813
Theory of 23,567
Surface Structure of:
Al 23,570
Cu, Damage in 23,568
Diamond 23,572
Fe Whiskers 23,569
Si Films 23,571
Susceptibility,
Defect Effects on 24,259
Measurement of 24,076
Susceptibility of:
CdS 24,081
$CdS:Ni^{2+}$ 24,082
CoO 24,086
$CoTiO_3$, Magnetic 23,591
Cr-Acetic Acid Salts 24,084
CrI_2, Temperature Dependence of 24,083
Diamond,
Diamagnetic 24,258
Paramagnetic 24,258
Eu_2O_3, Paramagnetic 24,257
Fe 24,171
Fe-V 24,171
$FeCd_2 \cdot 4H_2O$ 24,084
$FeCl_2$-$4H_2O$ 24,085
Gd 24,078
$GdPO_4$ 24,079
Ge,
Diamagnetic 24,258
Paramagnetic 24,258
MnHg, Antiferromagnetic 24,243
Mo,
Magnetic 24,259
Paramagnetic 24,259
Mo-Tc 24,080
Orthoferrites, Magnetic 24,207
Pt,
Magnetic 24,259
Paramagnetic 24,259
Rare Earth-NaMo Scheelites, Magnetic 23,801

Susceptibility of: (Cont'd)
Si,
Diamagnetic 24,258
Paramagnetic 24,258
Small Systems, Diamagnetic 24,313
Sn,
Diamagnetic 24,258
Paramagnetic 24,258
Superconductors (II) 24,029
ZnO:Ni^{2+} 24,082
ZnS:Mn^{2+} 24,077
Switch, Gate Turn-Off 24,574
Switching in Four Layer Diodes 24,573
Switching Circuits,
Bistable 24,753
Cryotron 24,805
Flip-Flop 24,752
Magnetic Core 24,754
Multivibrator 24,753
Switching Functions, Multiple Output 24,749
Switching System for Telephony 24,782,24,783
Switching Time of:
Grounded Emitter Circuits 24,750
Narrow Base Diodes 24,559
Tunnel Diodes 24,566
Switching Transistors, Power Dissipation in 24,586
Symmetrical Transistors, Fabrication and Characteristics of 24,598

T

Tantalum,
Dislocation-Interstitial Interactions in 23,682
Dislocation Relaxation in 24,555, 24,556
Internal Friction of 24,555, 24,556
Ion Emission from 24,066
Work Function of 24,067
Tantalum in Ge, Diffusion of 23,734
Tantalum Superconducting Films,
Critical Temperature of 24,011
Preparation of 24,011
Transitions in 24,013
Tunneling in 24,011
Tantalum Carbide, Free Energy of Formation of 23,527
Tantalum-Niobium Oxide, Crystal Structure of 23,595
Tapes, Magnetization Reversal in Ni 24,177
Tecnetrons, Characteristics of 24,591
Telegraphy, Message Processor for 24,787
Telephony,
Carrier Systems for 24,785
Data Transmission System for 24,786
Switching Systems for 24,782, 24,783
Traffic Measuring Equipment for 24,784
Television Cameras 24,776
Tellurium in GaAs, Diffusion of 23,743
Temperature Controls,
Phototransistor 24,833
Reactor 24,852
Temperature Measurements with (Ce-Mg)NO_3 24,841
Terbium, Compression of 24,527
Terbium Manganese ($TbMn_2$), Magnetic Structure of 24,095
Terbium Palladium ($Tb_{5.1}Pd_{1.9}$), Ferromagnetic 24,126
Thallium, de Haas-van Alphen Effect in 24,319
Thallium Selenide, Photoconductivity in 24,418
Thermal Conductivity, Theory of 24,475
Thermal Conductivity of:
CdS 23,868
CdTe 23,868
Chromite Spinels, Temperature Dependence of 24,483
Cu, Low Temperature 24,479
Ferromagnetic Metals 24,477
GaAs 23,868
GaAs, Irradiation Effects on 24,480
GaSb 23,868
InP 24,481
InSb 23,868
Thermal Conductivity of: (Cont'd)
Organic Semiconductors 23,938
Porous Media 24,476
Quartz Granules, Low Temperature 24,484
TiC 24,482
TiN 24,482
ZrC 24,482
Thermal Diffusion Equation, Solution of 23,725
Thermal Diffusivity of Insulators 24,485
Thermal Emf, Effect of Phonon Drag on 24,495
Thermal Emf of:
Ferromagnetic Metals 24,496
Ge 24,500
Thermal Etching of Cu-Si 23,818
Thermal Expansion, Measurement of 24,486
Thermal Expansion of:
Al 24,487
Al-Ag 23,625
AlSb 24,491
Cd 24,489
Ce, Linear 24,488
CoS_2 23,606
CsBr 24,474
Cu 24,490
FeS_2 23,606
GaSb 24,491
Ge 24,490
HgTe 24,491
In 24,489
KBr 24,474
KCl 24,474
NaCl 24,474
TiC 24,493
TiN 24,493
UC 24,494
ZnTe 24,491
ZrC 24,493
ZrN 24,493
ZrO_2:Y 24,492
Thermal Expansion-Defect Relationships 23,623
Thermal Properties, Variable-State Method of Measuring 24,478
Thermal Resistivity of:
PbTe-SnTe 23,832
Ru 23,967
Thermoelectric Power of:
$AuSb_2$ 23,994
$CrSi_2$ 23,993
Cu 24,498
Cu_2Sb 23,994
Ge, Hot Carrier 24,499
InS_3 23,834
NiO(Li) 23,941
Organic Semiconductors 23,938
SnTe 23,833
Zn_3Sb_2 24,075
Thermoelectric Properties of Ferromagnetic Metals 24,497
Thermoluminescence,
Measurement of 24,384
Normalization of Data on 24,383
Thermoluminescence of:
Amblygonite, Pressure Dependence of 24,387
KBr, Irradiation Effects on 24,385
KCl, Irradiation Effects on 24,385
KDP, Scintillations in 24,386
NaCl, Irradiation Effects on 24,385
Orthoclase, Pressure Dependence of 24,387
Pectolite, Pressure Dependence of 24,387
Scapolite, Pressure Dependence of 24,387
TGS, Scintillations in 24,386
Wollastonite, Pressure Dependence of 24,387
Thermomagnetic Coefficients of Semiconductors, Calculation of 24,503
Thermopile Radiation Detectors 24,839
Thin Film Bolometers 24,838
Thin Film Circuits,
Design of 24,694
Inductors for 24,695
Thin Film Oscillators 24,747
Thin-Film Transistors 24,596
Thin-Film Transistors, Metal Oxide 24,597
Thorium, Fluorescence of 24,392
Thorium Palladium (ThPd), Crystal Structure of 23,558
Thorium-Rhenium, Work Function of 24,068
Three-State Memory Units 24,813
Thulium Aluminum, Paramagnet Spin-Lattice Relaxation of Fe^{3+} 24,274
Thulium Gallium, Paramagnet Spin-Lattice Relaxation of Fe^{3+} in 24,274
Thyristors, Operation of 24,708
Time Delay Circuits 24,773, 24,774
Time Delay Circuits, Unijunction Transistor 24,775
Tin,
Electronic Structure of 23,872
Phase Transitions in 23,553
Susceptibility of 24,258
Tin Superconductors,
Surface Impedance of 24,023, 24,024
Ultrasonic Attenuation in 24,542
Tin Whiskers, Growth of 23,794
Tin-Aluminum Alloys, Heat of Solution of 23,531
Tin-Cadmium, Lattice Parameters of 23,607
Tin Disulphide,
Dislocations in 23,705
Glide Planes in 23,705
Stacking Faults in 23,705
Tin-Gallium Alloys, Heat of Solution of 23,531
Tin-Indium Alloys, Heat of Solution of 23,531
Tin-Indium Superconductors, Surface Impedance of 24,023
Tin-Rare Earth Alloys, Heat of Solution of 23,530
Tin-Silver Alloys, Heat of Solution of 23,530
Tin Telluride,
Carrier Concentration in 23,833
Energy Band Structure of 23,833, 24,435
Preparation of 23,833
Reflection from 24,435
Solubility of:
CdTe in 24,535
InTe in 23,535
Thermoelectric Power of 23,833
Transmission in 24,435
Titanium^{3+} in Al_2O_3, Paramagnetic Relaxation of 24,273
Titanium Carbide,
Atomic Vibrations in 24,493
Debye Temperature of 24,493
Plasticity of 24,520
Thermal:
Conductivity of 24,482
Expansion of 24,493
Titanium Carbon Nitride,
Carrier Density in 24,055
Energy Band Structure of 24,055
Hall Effect in 24,055
Titanium Dioxide,
Conductivity of 23,986
Dielectric Constant of 23,891
Growth of 23,800
Hall Coefficient of 24,054
Mobility of Electrons in 23,943
Paramagnetic Spin-Lattice Relaxation of Fe^{3+} in 24,275
Titanium Nitride,
Atomic Vibrations in 24,493
Debye Temperature of 24,493
Thermal:
Conductivity of 24,482
Expansion of 24,493
Titanium Vanadium Carbide,
Carrier Density in 24,055
Energy Band Structure of 24,055
Hall Effect in 24,055
Titanium-Rhenium Silicon, Crystal Structure of 23,585
Traffic Measuring Equipment for Telephony 24,783
Transceivers, UHF 24,779
Transient Characteristics of Transistors 24,583, 24,584
Transition Metals, Magnetic Carriers in Ferromagnetic 24,143

Transition Temperature of:
  Nb_3Sn Superconductors 24,022
  Nb-Zr Superconductors 24,022
  Zr Superconductors 24,021
Transistor Circuits,
  Emitter Coupled 24,705
  Grounded Emitter 24,704
  Noise in 24,706
  Temperature Dependence of 24,705
Transistors,
  Current Crowding in 24,581
  Field Effect 24,588, 24,589, 24,590, 24,591 24,592, 24,593, 24,707
  GaAs 23,743
  Graded Base 24,587
  Life Tests on Power 24,576
  Metal:
    Film 24,596
    Oxide Film 24,597
  Minority Carrier Storage in 24,582
  Noise in 24,585
  Operating Point of 24,704
  Planar 24,578, 24,599
  Power Dissipation in TV Switching 24,586
  Second Breakdown in 24,580
  Switching 24,578
  Symmetrical 24,598
  UHF Applications of 24,714
  Unijunction 24,594, 24,595, 24,709
  Testing of 24,577
  Theory of 24,579
  Transient:
    Characteristics of 24,583
    Response of 24,584
Transmission - See Also Absorption
Transmission in:
  As 24,435
  BaF_2, Infrared 24,355
  Bi 24,435
  CoF_2, Infrared 24,250
  GeTe 24,435
  Group:
    IV-VI Compounds 24,435
    V Semimetals 24,435
  $InAs_ySb_{1-y}$ Films 24,331
  MgO, Infrared 24,355
  $MnCO_3$, Infrared 24,250
  NiF_2, Infrared 24,250
  Pb-Group VI Compounds 24,435
  PbS 24,435
  PbSe 24,435
  PbTe 24,435
  Sb 24,435
  SnTe 24,435
  $SrTiO_3$ 24,341
Transmitters,
  HF 24,781
  Satellite Communication 24,780
Transport,
  Anharmonicities Effects in 23,937
  Calculation on 23,935
Transport in:
  Organic Semiconductors 23,938
  PbTe 23,940
  Semiconductors, Non-Ohmic 23,934
  ZnSb 23,939
Trapping in GaSb, Surface 24,423
Trapping Cross Sections 23,928
Trapping Cross Sections, Electric Field Effects on 23,927
Traveling-Wave Masers,
  Gain in 24,617
  Ruby 24,788
Trigger Circuits, Schmitt 24,751
Triglycine Sulfate,
  Electrostriction in 23,916
  Ferroelectric 23,904
  Polarization Reversal in 23,906
  Thermoluminescence of 24,386
Trigons on Twin Boundaries in Diamond 23,708
Tungsten,
  Defects in 23,619
  Desorption of K from 23,815
  Dislocation-Interstitial Interactions in 23,682
  Fermi Surface of 23,854, 24,227
  Mössbauer Effect for Fe^{57} in 24,400
  Optical Constants of 24,432
  Ultrasonic Attenuation in 24,540
Tungsten Carbide, Heat Content of 24,470
Tungsten-Carbon, Phase:
  Diagram of 23,550
  Transitions in 23,550
Tungsten Trioxide, Ferroelectric 23,899
Tunnel Diode:
  Amplifiers 24,733
  Coincidence Circuits 24,849
  Converters 24,758
  Counters 24,797
  Detectors 24,759
  Discriminators 24,849
  Memory Units 24,813
  Mixers 24,758, 24,759
  Oscillators 24,745, 24,746
  Pulse:
    Circuits 24,849
    Height Discriminators 24,766
  -RC Networks, Transfer Functions for 24,683
  Scalers 24,849
Tunnel Diodes,
  Excess Current in 24,568
  High Frequency Operation of 24,699, 24,700
  Negative Resistance of 24,565
  Reverse Current of Ge 24,567
  Switching Time of 24,566
Tunneling in:
  Nb Superconducting Films 24,011
  Ta Superconducting Films 24,011
  V Superconducting Films 24,011
Tunneling from Excited F-Centers 24,073
Twin Boundaries in Diamond 23,708
Twins, Electron-Diffraction Measurement of 23,710
Twins in:
  Au, Annealing of 23,707
  Calcite 23,683
  Cu Films 23,692
  Nb Foils 23,711
  NiO 23,709
  UC Films 23,757
  Zn 23,683

U

UHF Amplifiers 24,714
UHF Transceivers 24,779
Ultrasonic Absorption in Ga 24,544
Ultrasonic Attenuation, Coulomb Interaction in 24,537
Ultrasonic Attenuation in:
  Al 24,539
  Mo 24,540
  Mn Ferrite 24,534
  Ni 24,534
  Sn Superconductors 24,542
  Superconductors 24,541
  W 24,540
Ultrasonic Propagation in Piezoelectrics 24,536
Ultrasonic Wave Absorption in $CuSO_4$ 24,545
Ultrasonic Wave Amplification in Piezoelectrics 24,549
Ultrasonic Wave Damping in Metals 24,538
Ultrasonic Wave Velocity in:
  Dielectrics 24,546
  Mn Ferrite 24,354
  Ni 24,534
  PbS, Temperature Dependence of 24,548
  Semiconductors 24,547
  Semimetals 24,547
Ultrasonic Waves,
  Dispersion of 24,543
  Velocity of 24,511
Ultrasonic Waves in Dielectrics 25,535
Ultraviolet Reflection from:
  Al_2O_3 24,442
  BeO 24,442
  Diamond 24,322
  SiO_2 24,442
Unijunction Transistor:
  Multivibrators 24,740
  Relaxation Circuits 24,709
  Time Delay Circuits 24,775
Unijunction Transistors,
  Characteristics of 24,594
  Neuristor Line Using 24,595
Unipolar Transistors - See Field Effect Transistors
Unit Cell of Au_3Mn 23,605
Uranium,
  Fluorescence of 24,392
  Heat Capacity of 24,467
Uranium Superconductors,
  Energy Band Structure of 24,007
  Model for 24,007
Uranium Carbide,
  Heat Capacity of 24,468
  Thermal Expansion of 24,494
Uranium Carbide (UC) Films,
  Precipitation of UC_2 in 23,757
  Preparation of 23,757
  Twinning in 23,757
Uranium Dioxide,
  Conductivity of 23,987
  Hall Mobility of 23,987
  Mobility of 23,987
Uranium-Aluminum-Iron, Phase Diagram of 23,539
Uranium Fissium Alloys, Heat Capacity of 24,467
Uranium Molybdenum Carbide ($UMoC_2$), Crystal Structure of 23,592

V

Vacancies,
  Concentration of 23,624
  Diffusion of 23,624
Vacancies as Acceptors in ZnTe 23,970
Vacancies in:
  Ag, Annealing of 23,627
  Al 23,626, 24,524
  Al, Pits Caused by 23,630
  Al-Ag, Concentration of 23,625
  Al-Zn, Radiation Induced 23,753
  Alkali Halides, Annealing of 23,628
  Au,
    Annealing of 23,627
    Cluster at Twin Boundaries of 23,707
    Nucleation of 23,629
  β-Brass 23,624
  CdS 23,737
  Cu, Annealing of 23,627
  Cu_3Au, Formation of 23,556
  Diamond 23,631
  Fe 23,634
  Ge 23,631
  Si 23,631
  Conduction in Metal Oxides, Effect of 23,982
Vacancy-Dislocation Interactions 23,681
Vacuum Substrate Holders 23,774
Valence Band of:
  $PtSb_2$ 24,049
  ZnSb 24,323
Vanadium in GeO_2, Paramagnetic Resonance of 24,286
Vanadium^{2+} in MgO, Paramagnetic Resonance of 24,287
Vanadium^{3+} in Al_2O_3, Paramagnetic Resonance of 24,285
Vanadium Superconducting Films,
  Critical Temperature of 24,011
  Preparation of 24,011
  Tunneling in 24,011
Vanadium Carbide, Free Energy of Formation of 23,527
Vanadium Garnets, Ferrimagnetic 24,121

Vanadium Germanium (V_3Ge) Superconducting Films, Transitions in 24,013
Vapor-Liquid-Solid Growth of Crystals 23,767, 23,768
Vapor Etching of Ge 23,819
Vapor Doping:
  with GeI_2 23,722
  of Si Films 23,723
Vaporization of:
  Cd_3As_2 23,529
  GeTe 23,522
Varactor Diodes,
  Capacitance Variation in 24,698
  Tuning with 24,702
  Voltage-Elastance of 24,572
Video Amplifiers, Gain Controlled 24,726
Voigt Effect, Quantum Theory of 24,449
Voigt Ellipticity, Measurement of 24,451
Voltage-Elastance of Varactor Diodes 24,572

W

Web Growth of Semiconductors 23,777
Whiskers,
  Growth of:
    Co 23,795
    Fe 23,569
    Si 23,768
    Sn 23,794
    Zr 23,793
  Resistivity of:
    Ag 23,964
    Cu 23,964
    Fe 23,569
Wien Bridge Oscillators 24,743, 24,744
Wires,
  Resistivity of: 23,962
    Pt 23,985
Wollastonite,
  Thermoluminescence of 24,387
Work Function of:
  Ta 24,067
  Th-Re 24,068
Work Hardening in Ge 23,685
Wurtzite Crystals, Lattice Vibrations in 23,865

X

X-Band Amplifiers, Parametric 24,716
X-Ray Reflection Measurements 23,566

Y

Yield Strength of Metals, Grain Size Dependence of 24,529
Yielding in Fe, Pressure Effect on 24,531
Young's Modulus of:
  Ag 24,516
  Au 24,516
  Cu 24,516
Ytterbium,
  Compression of 24,527
  Electronic Structure of 23,849
  Fermi Surface of 23,849
  Phase Transitions in 23,551, 24,527
Ytterbium Manganate,
  Electric Ordering in 24,088
  Magnetic Ordering in 24,088
Yttrium Ferrogarnets, Magnetization of 24,174
Yttrium Gadolinium Selenide ($Y_{0.5}Gd_{1.6}Se_{2.9}$), Ferromagnetic 24,127
Yttrium Garnet,
  Ferromagnetic:
    Resonance in 24,208
    Resonance Line Width of 24,221
Yttrium Iron Garnet,
  Ferromagnetic Resonance in 24,214, 24,224
  Growth of 23,804
  Magnetization Reversal in 24,179
  Magnetoelastic Waves in 24,108
  Permeability of 24,170
  Spin Wave Pumping in 24,223
Yttrium Iron Garnet (Ion Substituted),
  Curie Temperature of 24,167
  Magnetic Structure of 24,167
  Magnetization of 24,167
Yttrium Iron Garnet:Si:Mn, Magnetic Anisotropy of 24,186
Yttrium Iron Garnet:Yb, Magnetic Anisotropy in 24,187
Yttrium Iron Garnet Spheres, Polishing of 23,826
Yttrium Manganate,
  Electric Ordering in 24,088
  Magnetic Ordering in 24,088
Yttrium Oxide, Growth of 23,800
Yttrium Oxide:Nd^{3+},
  Fluorescence of 24,669
  Stimulated Emission from 24,669

Z

Zinc,
  de Haas-van Alphen Effect in 24,318
  Dislocation-Twin Interactions in 23,683
  Growth of Dislocation Free 23,791
  Twinning in 23,683
Zinc in:
  GaP,
    Diffusion of 23,740
    Distribution Coefficient of 23,740
    Solubility of 23,740
  GaAs,
    Diffusion of 23,739, 23,740, 23,741, 23,742
    Distribution Coefficient of 23,740
    Solubility of 23,740
Zinc Antimonide,
  Absorption Edge in 24,323
  Carrier Concentration in 24,323
  Conductivity of 23,939, 24,075
  Effective Mass in 24,323
  Energy Gap of 24,075
  Growth of 23,939, 24,323
  Hall:
    Coefficient of 23,939
    Effect in 24,075
    Mobility in 24,323
  Magnetoresistivity of 23,939
  Mobility in 24,323
  Mobility of Holes in 24,075
  Optical Transitions in 24,323
  Thermoelectric Power of 24,075
  Transport in 23,939
  Valence Band in 24,323
Zinc Cadmium Sulfoselenide Phosphors-Luminors, Electroluminescent of 24,375
Zinc-Mercury, Crack Initiation in 23,713
Zinc Oxide, Paramagnetic Resonance of Iron Group Impurities in 24,283
Zinc Oxide:Ni^{2+}, Susceptibility of 24,082
Zinc Oxide-Eosin Films, Photoconductivity of 24,424
Zinc Oxide Phosphors, Electroluminescence of 24,374
Zinc Phosphate, Paramagnetic Resonance of:
  Cu^{2+} in 24,284
  Mn^{2+} in 24,284
Zinc Selenide,
  Lattice Parameters of 23,602
  Paramagnetic Resonance of Cr^{+} in 24,290
Zinc Selenide, (Cont'd)
  Photoconductivity of 24,419
  Refractive Index of 24,445
Zinc Sulfide,
  Absorption Edge in 24,361
  Crystal Structure of 23,577
  Data Sheets on 23,519
  Energy Gap of 23,842
  Ionic Charge in 23,842
  Junction Formation in 23,577
  Paramagnetic Resonance of Iron Group Impurities in 24,283
  Phase Transitions in 23,577
  Reflection from 24,438
  Reflectivity of 24,439
Zinc Sulfide:Cu:Al Phosphor, Electroluminescence of 24,379
Zinc Sulfide:Cu:Cl Phosphor, Luminescence of 24,4
Zinc Sulfide:Cu:Halogen Phosphors, Electroluminescent Deterioration in 24,380
Zinc Sulfide:Cu Phosphors,
  Electroluminescence of 24,377, 24,378
  Luminescence of 24,406
Zinc Sulfide: Mn^{2+},
  Absorption in 24,335
  Susceptibility of 24,077
Zinc Sulfide Phosphors,
  Electroluminescence of 24,374
  Photoluminescence of 24,390
Zinc Sulfide:Selenide:Cu Phosphors, Electroluminescence of 24,376
Zinc Sulfide Type Crystals, Lattice Vibrations in 23,863
Zinc Telluride,
  Conductivity of 23,970
  Paramagnetic Resonance of Cr^{+} in 24,290
  Refractive Index of 24,445
  Thermal Expansion of 24,491
Zinc Tungstate,
  Dislocations in 23,802
  Etching of Dislocations in 23,802
  Growth of 23,802
Zinc Yttrium (ZnY),
  Ferromagnetic Resonance Line Width of 24,206
  Growth of 24,206
Zinc Yttrium (Zn_2Y), Magnetoacoustic Waves in 24,230
Zincblende Crystals, Lattice Vibrations in 23,865
Zirconia:Y, Thermal Expansion of 24,492
Zirconium, Oxidation of 23,808, 23,809
Zirconium Superconductors, Transition Temperature in 24,021
Zirconium Whiskers, Growth of 23,793
Zirconium-Calcium Oxide,
  Conductivity of 23,988
  Order-Disorder Transitions in 23,988
  Phase Transitions in 23,988
Zirconium Carbide,
  Atomic Vibrations in 24,493
  Debye Temperature of 24,493
  Plasticity of 24,520
  Thermal:
    Conductivity of 24,482
    Expansion of 24,493
Zirconium Dioxide:Y, Thermal Expansion of 24,492
Zirconium Nitride,
  Atomic Vibrations in 24,493
  Debye Temperature of 24,493
  Thermal Expansion of 24,493
Zircotitanate, Ferroelectric Properties of 23,898
Zone Melting,
  Electric Current Effect on 23,763
  Theory of 23,720
Zone Melting of Ge 23,763
Zone Refining of InSb 23,779

AUTHOR INDEX

larenkov, I. 23,870
bgard, R.L. 24,646
tbott, H.M. 23,764
el, D. 24,603
el, W.R. 24,841
arikosov, N.K. 24,491
ket, G.A. 24,054
ams, L.H. 23,545
dis, B. 23,825
omines, A.A. 24,807
ro, E.L. 24,509
arwala, R.P. 23,748
aroni, A. 24,256
lers, G. 24,461
n, K.Y. 24,117, 24,092
zu, K. 23,897
asaki, I. 23,722
hundov, G.A. 24,418
imaru, H. 24,783
imchenko, I.P. 24,409
ramov, G. 24,538
ulov, N.S. 23,640, 23,647
bert, M.P. 23,959
berts, L. 24,156, 24,243
eksandrov, A.P. 24,174
eksandrov, K.S. 24,519
ekseerskii, N.E. 23,957
eonard, A. 24,096
ers, G.A. 23,670
exander, S. 24,091
ieva, M.K. 24,418
len, D.E. 24,722
lison, H.W. 23,844
lpress, J.G. 23,821
perin, H.A. 24,099
stetter, C.J. 23,795
'tshuler, S.A. 24,268
nar, H. 23,724
mbrose, T.P. 23,918
mbroziak, A. 24,595
nelinckx, S. 23,705
nirkhanov, K.I. 24,053
nstuta, G.C. 23,606
nand, M.S. 23,748
nderson, A.C. 24,841
nderson, C.J. 24,124
nderson, F.B. 24,239
nderson, J.L. 23,639
nderson, P.W. 24,091
ndres, R.K. 24,787
ndrewa, H.L. 24,149
ndrews, K. 23,598
ndrieveskii, A.I. 23,662
ndrushko, A.F. 23,611
ngino, E.E. 24,387
nsell, G.S. 24,092
nsel'm, L.N. 23,941
ntonoff, M.M. 24,128
ntonov-Romanovskii, V.V. 23,927, 23,928
qua, E.N. 23,691
rai, T. 24,327
rajs, S. 23,966, 24,257
rgyle, B.E. 24,159
rgyres, P.N. 24,262
rin, M.L. 23,524
rizumi, T. 23,722, 24,746
rmington, A.F. 23,721, 23,807
rmstrong, J.A. 24,626
rnold, G.P. 24,093
rora, R.P. 23,894
rrott, A. 24,171, 24,246
sanabe, S. 23,993
sano, S. 24,376
Asanuma, M. 24,225
Asayama, K. 24,302
Ascoli-Bartoli, U. 24,855
Ashburn, E. 24,631
Astheimer, R.W. 24,839
Astrue, R.W. 24,198
Atwood, J.R. 24,826
Aukrust, E. 23,526
Auld, B.A. 24,230
Austerman, S.B. 23,745
Autler, S.H. 24,005
Aven, M. 24,372
Averbakh, E.M. 24,075

Bacchilega, A. 23,685
Bagchi, R.N. 24,264
Bailey, G.C. 24,051
Baker, D.J. 24,713
Baker, G.S. 23,682
Balkanski, M. 24,350
Ball, M. 24,101
Balluffi, R.W. 23,625, 23,776
Balslev, I. 24,330
Bando, Y. 24,163
Banjamini, E. 23,810
Banus, M.D. 23,549
Baranowski, B. 23,968
Barker, L.M. 24,508
Barnett, W.P. 24,577
Barns, R.L. 23,718
Barton, C.J. 24,092
Baryakhtar, V.G. 24,242
Bashirov, B.I. 24,053
Basinski, S.J. 23,684
Baskinski, Z.S. 23,684
Bassett, H.G. 24,587
Bassi, G. 24,096
Basu, M.S. 24,749
Bate, F.D. 24,586
Bate, G. 24,176
Bauer, C.L. 23,664
Baugh, C.W. 24,647
Baumgardt, N.R. 23,618
Bauminger, E.R. 24,104
Baur, H. 24,782
Beam, W.R. 24,092, 24,117
Beaman, D.R. 23,625
Beaudry, B.J. 24,351
Bechmann, R. 24,770
Becke, H. 23,741
Becker, S. 24,758
Becker, W.M. 24,048
Beckman, O. 24,517
Beddoes, M. 24,762
Beeler, Jr., J.R. 23,618
Beerntsen, D. 23,599
Beilin, V.M. 24,507
Belikov, B.P. 24,519
Bell, R.L. 24,522
Bellman, R.E. 23,725
Belson, H. 23,826
Belus, R. 24,785
Belyaer, A.D. 23,929
Belyaera, A.I. 24,339
Belyayev, L.M. 23,758
Benci, S. 23,556
Bengus, V.Z. 23,683
Bennemann, K.H. 23,631
Bennett, A.I. 23,777
Berdyshev, A.A. 24,132
Bergman, B. 23,583
Berkebile, A. 23,800
Berkowitz, A.E. 24,126
Bernal, J.R. 23,622
Bernard, M.G.A. 24,665
Bernard, W. 24,576, 24,568
Bernard, W.J. 23,570
Berry, B.S. 23,972
Bertaut, E.F. 24,096
Bertoya, H.C. 24,710
Beshers, D.N. 23,657
Bhawalkar, D.D. 24,655
Biard, J.R. 24,620
Bibik, V.F. 24,064
Bierig, R.W. 24,274
Bills, J.L. 23,525
Bir, G.L. 24,263
Birnbaum, M. 24,656, 24,663, 24,765
Bishop, G. 23,825
Bisi, A. 23,871
Bither, Jr., T.A. 23,799
Blakemore, J.S. 23,953
Blank, S.L. 23,749
Blank, Y.S. 24,405
Blatt, F.J. 24,498
Blattner, D.J. 24,676, 24,677
Blau, Jr., H.H. 24,432
Blevin, W.R. 24,434
Blocher, C.L.M. 23,765
Blocker, T.G. III 24,218, 24,219
Bloom, L. 24,613
Bloom, M. 24,103
Bloomfield, M. 23,765
Blotekjaer, K. 24,549
Blue, M.D. 24,334
Blume, A.E. 24,643
Blust, E.D. 24,766
Boato, G. 23,831
Boerio, A.H. 24,061
Bogdanov, S.V. 23,892
Boija, S. 24,329
Bokov, V.A. 24,088
Bolgiano, Jr., L.P. 24,601
Boltaks, B.I. 23,730, 23,744
Bolton, H.C. 24,300
Bonch-Bruevich, V.L. 23,843, 23,921, 24,321
Bonfield, W. 24,522
Bonfiglioli, G. 23,620
Booker, G.R. 23,783
Borisov, V.T. 23,866
Boron, M.P. 23,750
Borrelli, N.F. 24,667
Borzhkovskaya, V.M. 23,672, 23,673
Boswarva, I.M. 24,450
Bowen, D.E. 23,546
Bowman, N. 24,673, 24,675
Boyarskaya, Y.S. 23,686
Boyle, P. 24,735
Boyle, W.S. 24,649
Bozorth, R.M. 24,100
Bradley, J.E. 24,633
Bradley, R. 24,528
Bragg, R.H. 23,822
Brailsford, A.D. 24,476
Brand, F.A. 24,642
Brandt, N.B. 24,314
Brault, J.W. 24,660
Braunstein, R. 24,332
Bray, H.J. 23,607
Brebrick, R.F. 23,528, 23,833
Brennemann, A.E. 24,805
Brinkworth, B.S. 24,485
Brodsky, M.B. 24,304
Brog, K.C. 24,312
Bron, W.E. 24,365
Bronzite, M. 24,712
Brooks, H. 24,131
Bross, H. 23,836
Brown, B. 23,599
Brown, L.J. 24,653
Brown, R.D. 24,039
Brown, R.E. 24,777
Brugger, K. 24,510, 24,511
Brumage, W.H. 24,077, 24,082
Brunner, G.O. 24,384
Bryan, M.E. 24,756
Brzozowski, J. 24,681
Bube, R.H. 24,414
Buchanan, D.N.E. 24,399
Buhrer, C.F. 24,447, 24,453, 24,613
Bullen, F.P. 24,531, 24,533
Bullough, R. 23,676
Bulyanitsa, D.S. 23,919
Burckhardt, C.B. 24,047
Burgiel, J.C. 24,249
Burmeister, R.A. 23,536, 23,781
Burns, G. 24,627, 24,876
Burov, I.V. 24,078
Burshtein, A.I. 24,427
Bursian, E.V. 23,805
Burstein, E. 24,330
Bussey, H.E. 24,212
Butcher, I.R. 24,809, 24,814
Butler, C.T. 23,644
Butterton, R.B. 24,722
Byrne, J. 23,666

Cable, J.W. 24,094
Caddes, D.E. 24,610
Cadoff, I.B. 23,832
Cahn, R.W. 23,693
Caldwell, R. 24,607
Callen, E.R. 24,107
Callen, H.B. 24,135, 24,138, 24,239
Calvo, C. 24,284
Cape, J.A. 24,471
Cappelletti, R.L. 24,351
Cardona, M. 24,435, 24,438
Carey, R. 24,226
Carlin, H.J. 24,685
Carlson, W. 23,989
Carpenter, S.H. 23,682
Carr, R.H. 24,486
Carr, W. 24,368, 24,620
Carrison, L.C. 23,575
Carvajal, R. 24,799
Casabella, P.A. 23,877
Cass, T.R. 23,703
Castro, C.D. 24,015
Ceresara, S. 23,753
Chambers, J.G. 24,284
Chambers, R.H. 24,553, 24,555, 24,556
Champness, C.H. 24,052
Chan, F.L. 23,602
Chan, S. 23,606
Chang, J.T. 24,114
Chang, K.K.N. 24,759
Chang, L.L. 23,740
Chapman, F.W. 24,185
Charap, S.H. 24,133, 24,159
Charters, M.L. 24,667
Chasanov, M.G. 23,587
Chase, P.E. 24,759
Chechernikov, V.I. 24,078
Chechurin, S.M. 24,357
Checinska, M.H. 23,834
Chen, C.W. 24,106
Chen, D. 24,452
Cheng, K.L. 24,014
Chernov, A.A. 23,758
Chesebro, J. 24,739
Chevreton, M. 24,096
Chiao, R.Y. 24,618
Childambaram, R. 23,565
Childs, C.B. 24,848
Childs, W.J. 23,872
Chin, G.Y. 24,149
Chipman, J. 23,527
Chirkin, G.K. 24,298
Chkhartishvili, Y.V. 24,265
Choi, J.Y. 23,731
Chou, Y.T. 23,679
Choudhury, A.K. 24,749
Chow, P.E.K. 24,803
Christian, J. 23,674
Christian, J.W. 23,696
Chudinov, A.A. 24,548
Chyung, C.K. 23,791
Claiborne, L.T. 24,542
Clapp, P.C. 24,134
Clarebrough, L.M. 23,627
Clark, A.E. 24,107
Clark, A.P. 24,786
Clark, R.L. 23,727
Clarke, B.H. 24,204
Clarricoats, P.J.B. 24,223
Cloud, W.H. 24,162
Cockett, G.H. 24,833
Cohen, M.L. 24,009
Cohen, M.S. 24,115
Cohen, S. 24,609
Coleman, A.J. 24,002
Coles, B.R. 23,969
Colin, R. 23,522
Collins, T.C. 24,436
Colvin, R.V. 23,966, 24,257
Comanescu, V. 24,765
Combs, J.F. 23,959
Comer, J.J. 23,613
Compton, W.D. 23,646
Comstock, R.L. 24,228
Conard, G.P. 23,701
Condon, J.H. 23,852, 24,316
Constantine, Jr., W. 24,754
Copeland, W.D. 23,557
Corenzwit, E. 23,996
Corliss, L.M. 24,095
Corneretto, A. 24,797
Corning, J.J. 24,793
Correard, L.P. 24,787
Corsan, J.M. 23,963
Costa, G. 24,778
Cotti, P. 24,046
Cotton, F.A. 23,525
Courtney, W.E. 24,223
Cox, D.E. 24,098
Croft, W.J. 23,596
Cromer, D.T. 23,592
Crowley, T.H. 24,802
Crowell, C.R. 24,069
Cuff, K.F. 24,040, 24,371
Cummings, J.P. 24,458
Curtis, Jr., O.L. 23,924
Cusano, D.A. 24,372
Cushing, V. 24,842
Czerwonko, J. 24,237

Dakhovskii, I.V. 23,945, 24,503
Dakin, C.J. 24,737
Damask, A.C. 23,971
Damon, D.H. 24,049
Damsky, B.L. 23,643
Danielian, A. 24,236
Daniels, W.B. 23,990
Danilychev, V.A. 23,983
Danilycheva, N.N. 24,472
Darnell, F.J. 24,162
Das, D. 24,076
Das, S.R. 24,749
Das, T.P. 23,874
Datars, W.R. 24,284
Daunt, J. 24,046, 24,160
Dautreppe, D. 24,097
Davids, D.A. 24,277
Davies, A.C. 24,803
Davies, D.C. 24,752
Davis, E.M. 24,793
Davies, J. 24,148
Davies, R.G. 23,693
Davis, B.L. 23,545
Davis, H.L. 24,142
Davydov, L.A. 24,211
Dawe, P.G.M. 24,835
Dayal, B. 24,459
Dean, P.J. 24,366
Deaton, B.C. 23,546
DeBruin, H.J. 23,727
De Carlo, J.A. 23,619
DeClaris, N. 24,679
de Graaf, A.M. 24,488
Dekhtyar, I.Y. 24,154, 24,259
Delapalme, A. 24,096
Delavignette, P. 23,705
Delgrosso, E.J. 23,811
Del Grosso, R. 24,124
De Lotto, I. 24,766
DeMaria, A. 24,535
Demikhovskii, V.Y. 24,146
Demeshina, A.I. 24,441
Denayer, M. 23,987
DeNee, P.B. 24,484
Denning, R.M. 23,574
DeSavage, B.F. 24,107
Dettman, K. 23,860
Deutsch, J. 23,961
Dev. I. 24,378
Devreese, J. 23,987
DeVries, K.L. 24,525
DeWames, R.E. 24,471
Dickinson, J.M. 23,542
Diclue, J.L. 24,732
DiDomenico, Jr., M. 24,320
Dienes, G.J. 23,633
Dietz, R.E. 24,668
Dillamore, I.L. 23,690
Dillon, G.F. 23,721
Dillon, Jr., J.F. 24,205
DiMartini, R. 23,666
Dixon, Jr., S. 24,206
Dodd, D.M. 23,718
Doherty, P.E. 23,630
Dohi, S. 23,573
Dolgolenko, T.F. 24,314
Domanskaya, L.I. 24,504
Donachie, Jr., M. 23,543
Donaghy, J.J. 23,848, 23,850
Dorain, P.B. 24,291

Dormont, H. 24,604
Douglas, A.E. 24,336
Doyama, M. 23,626
Doyle, W.D. 24,189
Dmitriev, V.A. 23,611
Dmitrieva, L.V. 24,307
Dragon, R. 24,074
Drautman, J.J. 24,124
Drefke, O. 24,769
Dresselhaus, G. 24,090
Drew, J.B. 23,724
Drokin, A.I. 24,164
Drowart, J. 23,522
Drozdova, L.N. 23,978
Dubenskii, K.K. 24,335
DuBose, C.K.H. 23,711
Dubrovskaya, I.N. 24,500
Dubinin, V.I. 24,174
Duchane, E.M. 24,432
Duddridge, G. 24,569
Dudkowski, S.J. 24,424
Dufault, R.A. 24,646
Duffek, E. 23,810
Duffin, W. 23,585
Dumbaugh, W.H. 24,667
Duncan, Jr., R.C. 24,648
Dungan, R. 23,901
Dunham, R.L. 24,358
Du Plessis, P.D.V. 24,243
Duraffourg, D. 24,665
Durdaller, C.G. 23,553
Dweck, J.A. 24,299
Dyson, D. 23,598
Dzhafarov, T.D. 23,730
Dzyub, I.P. 24,347

Eales, L.W. 24,831
Eckart, D.W. 24,190
Eckstein, S.G. 24,071
Edmondson, B. 23,653
Egan, Jr., E.P. 23,523
Egorov, V.S. 23,957
Eibschutz, M. 24,168
Einspruch, N.G. 24,152, 24,542
Eisele, J.A. 24,847
Eisen, F.H. 23,632
Ekvall, R.A. 24,011
Ellett, M.R. 24,040
Elliott, J.F. 23,548
Ellis, W.C. 23,768
ElSaffar, Z. 24,247
Embree, J. 24,817
Engelkemeir, D. 24,392
England, R.E. 23,596
Englert, F. 24,128
English, F. 24,562
Entenmann, R. 24,819
Epstein, A.S. 23,786
Eremenko, V.V. 24,339
Erezhepov, M.E. 23,951
Ermachenko, V.M. 23,880
Ero, J.W. 24,588
Ero, J.W. 24,588
Ertelis, U. 23,729
Espinosa, G.P. 24,121, 24,122, 24,167
Estle, T.L. 24,283
Etter, D. 23,719
Evans, P.R.V. 23,712
Evans, R.J. 23,571
Euwema, R.N. 24,078
Eyre, B.L. 23,757

Falk, H. 24,234
Falkvik, I. 23,884
Fan, H.Y. 24,048, 24,323, 24,391, 24,421, 24,423
Fang, F.F. 24,564
Fang, J.H. 23,591
Faraday, B.J. 23,636
Farber, M. 23,524
Farnell, G.W. 24,266
Farnsworth, H.E. 23,572
Farrell, E.F. 23,800
Fattal, L. 24,772
Federighi, T. 23,753
Fedotov, Y. 24,697
Fedulov, M.V. 23,616
Feigelson, R.S. 24,079
Feltyn, I. 23,729
Fenerty, J. 23,960
Fenner, N.C. 24,850
Ferretti, A. 23,771
Feucht, D. 23,955
Feucht, D.L. 23,954
Fiegel, L. 23,544, 23,594
Filloux, J. 24,555
Fine, S. 24,854
Fink, H.J. 24,217, 24,255
Finnemore, D.K. 24,351
Fiorentini, A. 23,871
Firsov, Y.A. 23,896, 24,059
Fischler, S. 23,792
Fistul, V.I. 24,504
Flamm, D.L. 24,812
Flanders, P.J. 24,188
Flannery, W. 24,807
Flatley, D. 23,741
Fleisher, H. 24,822
Flinn, J.E. 24,526
Flippen, R.B. 24,087
Flores, J. 24,600
Flynn, C.P. 23,621
Foglesong, R. 24,690
Fok, M.V. 23,842
Fonda, E. 24,706
Foner, S. 24,317
Foreman, A.J.E. 23,676
Forsten, J. 23,790
Forster, J.H. 24,575
Forsvoll, K. 24,036
Fotchenkov, A.A. 23,916
Fowler, A.B. 24,623
Fowler, V. 24,613
Frait, Z. 24,216
Frankevich, D.P. 23,584
Frantz, L.M. 24,637
Fraser, H.J. 24,844
Frederikske, H.P.R. 23,992
Freeman, A.J. 23,875, 24,104
French, R.D. 23,784
Frenkel, A.S. 24,483
Fridkin, V.M. 24,408
Friedberg, S.A. 24,084, 24,085
Frieden, B. 23,788
Friedman, L. 23,938, 24,313
Frisch, H.L. 24,037
From, W.H. 24,291
Fuakai, A. 24,557
Fujii, M. 24,518
Fujimori, H. 24,182
Fujita, F.E. 23,971
Fujita, H. 23,936
Fujiwara, T. 23,573
Fukai, M. 24,057
Fuks, V.B. 23,944
Fukuchi, M. 23,839
Fukushima, M. 23,861
Fuller, C.S. 23,844
Fuller, G. 24,389
Furlan, J. 24,731, 24,755
Furukawa, G. 23,962
Furusho, K. 23,755

Gage, D. 24,607
Gaines, J. 24,160
Gainin, D. 24,448
Gallagher, P.K. 24,399
Gamba, O. 23,732
Gambling, W.A. 24,655
Gandelman, G.M. 23,880
Ganssen, A. 24,748
Garbrecht, K. 24,723
Garcia, M.F. 23,934
Gardiner, Jr., W.C. 24,763
Garmire, E. 24,618
Garwin, R.L. 24,303
Gasparrini, G. 23,556
Gatos, H.C. 23,549
Gedwill, M.A. 23,795
Gell, M. 23,714
Geller, S. 24,121, 24,122 24,167
Gendelev, S.S. 24,220
Genkin, G.M. 24,174, 24,241
Gentry, F. 24,573
George, T.V. 24,857
Geppert, D.V. 24,596
Gereth, R. 23,869, 24,570
Germagnoli, E. 23,556
Gershenzon, M. 24,370, 24,422
Gershenzon, E.M. 24,038
Gesi, K. 23,890, 24,282, 24,354
Ghosh, S.K. 23,855, 24,218, 24,219
Ghosh, U.S. 24,264
Gianola, F. 24,802
Gianola, U.F. 24,114
Gibbs, D.F. 23,889
Gibbs, P. 24,525
Gibson, J.W. 24,032
Gielisse, J. 24,400
Gilbert, E.R. 24,526
Gilbert, J.F. 23,857
Gillis, J.E. 24,810
Gingrich, N.S. 23,564
Ginsberg, D.M. 24,351
Giorgis, J. 24,578
Giraud, L. 24,785
Girifalco, L.A. 23,623, 23,624, 23,681
Gitsu, D.V. 23,845
Gladyshevskii, E.I. 23,584
Glasner, A. 24,337
Glinchuk, K.D. 23,926
Gloge, D. 24,671
Goetze, G.W. 24,061
Gold, L. 24,456, 24,560
Goldberg, N. 24,109
Golding, R. 23,901
Golding, R.M. 24,281
Goldman, A. 24,355
Goldman, H. 24,780
Goldsmid, H.J. 23,963
Goldsmitts, G. 23,770
Goldstein, A. 24,317
Goldstein, L. 24,857
Golikova, O.A. 24,500
Gomayunova, M.V. 24,062
Gomes, A.A. 24,488
Gondi, P. 23,685
Gondo, Y. 24,181, 24,452
Gonzalo, J.A. 23,904
Goodman, A.M. 23,828, 23,829
Goodman, L.S. 23,872
Gorban, I.S. 24,362
Gorbenko, P.K. 24,403
Gordon, D.I. 24,112
Gor'Kov, L.P. 24,004
Gorodetskii, A.F. 23,975
Gorodetsky, G. 24,168
Gosar, P. 23,952
Gossick, B. 24,562
Goto, T. 24,192
Grabowski, S.J. 24,678
Grafham, D.R. 24,574
Graham, G. 24,489
Graham, R. 24,780
Gran, B.E. 24,181
Grant, R.M. 24,454
Grant, W.J.C. 24,272
Grantham, R.E. 24,670
Gray, Jr., J. 24,832
Gray, L. 24,780
Green, A. 24,195
Green, D. 23,689
Green, M. 24,061
Green, Jr., R.E. 23,762
Greenaway, D.L. 24,435
Greenaway, P.E. 24,587
Greenbaum, M.A. 23,524
Greenwood, G.W. 23,706
Gregg, R.A. 23,537, 23,752
Greifer, A.P. 24,110
Grierson, R. 23,535
Griffin, O.G. 24,843
Grigsby, D.L. 23,519
Grimes, C.C. 24,232
Grimmeiss, H.G. 24,369
Grodzins, L. 24,104
Grohman, A. 23,964
Gross, E.F. 24,401
Grossweiner, L.I. 24,424
Grove, A. 24,559
Groves, W.O. 23,786
Gruen, D.M. 23,538
Grundy, P.J. 24,191
Gubanov, A.I. 23,862
Guggenheim, H.J. 24,668
Gunn, J.B. 23,998
Gunn, M. 23,885
Gupta, K.P. 23,600
Gurevich, G.L. 24,174
Gurevich, L.E. 23,997, 24,496
Gurvich, Y.A. 24,038, 24,056
Gurzhi, R.N. 23,937
Gustafson, D.R. 23,849
Gut, R. 23,538
Guyer, R.A. 24,543
Gvaladze, T.V. 24,342
Gyftopoulos, E.P. 23,814, 24,068
Gyorgy, E.M. 24,186

Haanlin, W.O. 24,752
Habegger, M.A. 24,423
Haga, E. 24,353
Hahn, E.L. 24,309
Haitz, R.H. 24,570
Hakim, E.B. 24,581
Halden, F.A. 23,518
Hall, R.N. 24,630
Hall, T.P.P. 23,641
Halley, J.W. 24,392
Halpern, J. 24,449
Halpern, O. 24,152
Hamilton, D.C. 24,007, 24,021
Hamilton, D.J. 24,583
Hanamura, E. 23,956
Hanneman, R.E. 23,549
Hansen, E.L. 23,773
Hanson, G. 24,607
Harada, J. 23,580
Haraya, K. 24,000
Harbeke, G. 24,438
Harding, W.E. 24,793
Hargreaves, M.E. 23,627
Harker, K.J. 24,141
Harlow, R.A. 23,732
Harmathey, T.Z. 24,487
Harper, H. 24,555, 24,556
Harper, P. 24,840
Harrington, L.C. 24,468
Harris, A.B. 24,235
Harris, R. 24,833
Harrison, A. 24,791
Harrison, R.W. 23,811
Hart, Jr., H.R. 24,029
Hartelius, C.C. 24,150
Harvey, D.J. 23,950
Hasegawa, A. 23,973
Hasegawa, M. 23,912
Hasiguti, R.R. 24,552
Hastings, J.M. 24,095
Hatcher, R.D. 23,633
Hatherly, M. 24,145
Hatkin, L. 24,642
Haumovets, A.G. 23,815
Hauser, J.J. 23,769, 24,012, 24,013
Hayes, A.R. 24,753
Healy, J. 23,544
Hearn, B.R. 24,147
Heartz, R.A. 24,818
Heberle, J. 24,400
Heck, C. 24,157
Heeger, A.J. 24,155, 24,218, 24,219, 24,253
Heer, C.V. 24,462
Hein, R.A. 24,032
Heine, V. 23,870
Heinlein, W. 24,723
Heinrich, B. 24,216
Heller, H.B. 23,736
Heller, W.R. 24,365
Hempstead, C.F. 24,017
Henchman, M. 24,281
Henderson, B. 23,608, 23,756
Henderson, F. 24,531
Henly, H.R. 24,594
Henning, H.B. 24,719
Henning, R.G. 23,794
Herczog, A. 23,893
Herkart, P.G. 24,664
Herrmann, G.F. 24,207, 24,300
Herrmann, W. 24,508
Herz, R.H. 23,614
Heyerdahl, N.E. 23,950
Hiatt, R.S. 24,776
Hickmott, T.W. 24,597
Hildalgo, A. 24,352
Higa, W.H. 24,614
Higgins, R.J. 24,318
Hilberg, W. 24,764
Hill, E.R. 23,949
Hill, G.J. 23,8
Hill, N.W. 24,8
Hiller, G. 24,7
Hiller, M.A. 23,8
Hilsum, C. 24,6
Hilt, R.L. 24,3
Hindley, N.K. 24,0
Hirakawa, K. 24,1
Hirayama, C. 24,3
Hirose, H. 23,8
Hirota, R. 24,0
Hirsch, A.A. 24,1
Hirsch, P.B. 23,6
Hirschhorn, J.S. 23,7
Ho, L. 24,447, 24,4
Hobart, R.H. 23,6
Hochmuth, H. 24,7
Hodges, J.A. 24,2
Hodgskiss, B.J. 24,8
Hoerni, J.A. 24,5
Hoesterey, D.C. 24,4
Hoffins, C.C. 24,7
Hoffman, R.A. 24,
Hohenberg, P. 24,0
Holland, C.E. 24,7
Holland, M.G. 23,8
Holleran, T.T.J. 24,0
Holm, J.D. 24,1
Holmes, D. 24,6
Holmes, D.A. 23,95 23,955
Holmes, J.S. 24,67 24,675
Holmes, L. 23,8
Holonyak, Jr., N. 24,6
Holton, W.C. 24,2
Holtzberg, F. 24,12 24,127
Holwech, I. 24,0
Honjo, G. 23,5
Hooper, Jr., E.T. 24,7
Hoper, J.H. 24,8
Hopkins, C.D. 23,7
Hopkins, M. 23,7
Hori, J. 23,8
Horn, W.E. 24,6
Hornreich, R.M. 24,1
Hoskino, M. 24,1
Hoshino, R. 24,2
Hoskins, R.H. 24,39 24,669
Hosler, W.R. 23,9
Housey, L. 24,7
Houska, C.R. 24,4
Houston, T. 24,1
Houzvicka, F. 23,7
Hovi, V. 24,3
Howard, W.E. 24,5
Howe, L.M. 23,7
Howell, E.K. 24,7
Hubbard, P.S. 24,3
Hubner, K. 23,8
Huggett, G.R. 24,4
Hughes, D.G. 24,3
Hughes, J. 23,6
Hulliger, F. 23,8
Hulm, J.K. 24,0
Hultstrand, K.A. 24,8
Hummel, F.A. 24,3
Humphrey, B. 24,1
Humphrey, F.B. 24,1
Hurle, D.T.J. 23,7
Hutchison, M.M. 24,5
Hutton, D.R. 24,2

Iaffe, I.V. 23,9
Iberson, E. 23,5
Ihoue, M. 23,8
Iida, K. 24,7

da, S. 23,709, 23,819
zeda, T. 23,915
koma, H. 24,000
ina, M.A. 24,022
nai, I. 24,057
naba, F. 24,645
silevskii, Y. 24,457
vine, J.A. 24,840
aac, E.D. 24,226
habashi, Y. 23,864, 23,899
higuro, T. 23,979
hii, K. 24,700, 24,730
shikawa, Y. 24,260
kra, V.D. 24,072
smailov, Z.A. 24,053
ah, F. 24,055
rakura, M. 24,070
oh, J. 24,302
oh, N. 23,628
skevich, E.S. 24,022
uesdal, T.A. 24,691
vanov, G.A. 23,845, 23,981, 24,045
wasa, S. 24,330
wasaki, H. 23,654
zuyama, T. 24,143

accarino, V. 24,308
accodine, R.J. 23,665
acobs, H. 24,642
acobsson, R. 23,774
affe, B. 23,995
ames, C.E. 24,558
anak, J.F. 24,193
anosi, A. 23,581
ansen, R. 24,096
iaslowski, S. 24,700
lasperse, J.R. 23,630
layaraman, A. 24,021
leanes, Jr., R. 24,639
lefferts, K.B. 24,252
leffery, J.W. 23,566
lelsma, L.F. 24,601
lessen, F.A. 24,653
lensen, M.A. 24,007
iensen, R.A. 24,751
leynes, G.F. 24,834
limmerson, B.D. 24,811
loenk, R.J. 24,175
lohari, O. 23,710
lohnson, H.C. 24,676
lohnson, L.F. 24,442, 24,668
lohnson, R.A. 23,634
lohnston, T.L. 24,530
lohnston, W.G. 24,521
lona, F. 23,787
lones, B.K. 24,539
lones, C.K. 24,227, 24,540
lones, E.D. 24,252
lones, L.H. 24,366
lones, S. 24,382
lones, Jr., W.H. 24,312
loseph, A.S. 24,020, 24,315
loshi, S.K. 24,490
lunginger, H.G. 23,836
lusti, E. 23,939
lustin, D. 23,952

Kabalkina, S.S. 23,554
Kabler, M.N. 24,373
Käch, A. 24,760, 24,761
Kadyshevich, A.E. 24,507
Kafalas, J.A. 23,833
Kagan, Y. 24,457
Kahan, A. 24,325
Kainuma, S. 24,645
Kalaba, R.E. 23,725
Kalbitzer, S. 23,645
Kallman, H. 24,768
Kama, A. 24,389
Kamimura, H. 24,248
Kaminow, I.P. 24,612
Kaneev, M.A. 23,617
Kannewurf, C.R. 24,820
Kanz, J.A. 23,742
Karkhanin, Y.I. 24,381
Karlsons, D. 24,661
Karmen, K.N. 23,909
Karpenko, B.V. 24,132
Kasen, M.B. 23,818
Kashcheer, V.N. 24,348, 24,349
Kask, N.E. 24,271, 24,273
Kastyukova, Y.P. 23,656
Katzman, M. 24,658
Kauffman, J.W. 24,524
Kaufman, A.B. 24,592
Kawai, T. 23,936
Kawamura, H. 24,057
Kawasaki, T. 23,979
Kay, A.E. 24,466
Kedzie, R.W. 24,289
Keesom, P.H. 24,465
Keith, H.D. 23,658, 23,760, 23,761
Kelley, P.L. 24,262
Kelly, A. 23,532
Kendall, E.J.M. 23,577
Kennedy, J.K. 23,710
Kern, W. 23,741
Kerrigan, J.V. 23,764, 24,222
Kestigian, M. 23,770, 24,289, 24,664
Ketolainen, P. 24,346
Kettunen, P. 23,790
Kevane, C.J. 23,982
Khachaturyan, A.G. 24,089
Khaikin, M.S. 23,853
Khaimov-Malkov, V.Y. 24,342
Khansevarov, R.Y 24,410
Kharakhash'yan, E.G. 24,545
Khilko, G.I. 24,335
Kholodar, G.A. 24,425
Kiess, H. 24,412
Kikoin, I.K. 24,367
Kikuchi, S. 24,041
Kim, Y.B. 24,017
Kimura, H. 24,353
Kinase, W. 23,864, 23,899
King, H. 23,715
King, S. 24,693
Kipling, A.L. 24,052
Kim, J.F. 23,789
Kirsch, J. 24,059
Kiruchi, C. 24,287, 24,291
Kiss, Z.J. 24,648
Kitamura, N. 23,563, 23,580
Kiusalaas, J. 23,675
Kleiman, D.A. 24,363
Klein, E. 24,854
Klein, M.W. 24,123
Kleinberg, R. 24,247
Kleiner, W.H. 24,005
Klick, C.C. 24,345
Klyshko, D.N. 24,270
Kneisel, O. 24,782
Knopf, G. 24,784
Knox, R.S. 24,345
Kobayashi, K. 23,936
Kobayashi, M. 23,956
Kobayashi, S. 24,302
Koda, S. 23,698
Kodera, S. 23,563
Koehler, J.S. 23,626
Koehler, W.C. 24,094
Koenig, J. 23,995
Koester, C.J. 24,792
Kogelnik, H. 24,641
Kohn, J.A. 24,190
Kohn, K. 23,709
Koike, R. 23,942
Koizumi, H. 23,903
Kolomoets, N.V. 23,917
Kolomoitsev, F.I. 24,377
Komatsubar, A.K. 23,999
Komiya, H. 24,323
Komnik, S.N. 23,683
Kondorskii, E.I. 24,083, 24,501, 24,502
Konobeer, Y.V. 23,881, 23,948
Konozenko, I.D. 24,417
Konyukhov, V.K. 24,342
Kooi, C.F. 24,222
Koopman, D. 23,609
Koppenaal, T.J. 23,712
Kopski, R.L. 24,702
Koritke, H. 23,552
Kornienko, L.S. 24,271, 24,273
Kornstein, E. 24,790
Korobkov, I.I. 23,612
Korol, E.N. 23,863
Korpel, A. 24,698
Korringa, J. 24,137
Korsun, V.M. 24,377
Koshiba, T. 24,750
Kostina, T.I. 24,083
Kouvel, J.S. 24,150
Kozlova, T.N. 24,083
Kozyrev, Y.P. 24,367
Krasnopertser, V.V. 23,914
Krebs, Jr., G.N. 23,639
Kreitman, M. 24,046
Kreitman, M.M. 24,081
Krembs, G.M. 24,563
Kretschmar, G. 24,331
Kripyakevich, P.I. 23,584
Krishna, R. 24,774
Kristofel, N.N. 23,859
Kronmuller, H. 24,151
Kropschot, R.H. 24,019
Krumhansl, J.A. 24,543, 24,546
Ksendzov, Y.M. 23,941
Ku, R.C. 24,530
Ku, W.H. 24,720, 24,721
Kubo, R. 24,143
Kudman, I. 24,481
Kukushkin, L.S. 24,324
Kulcke, W. 24,822
Kuliyev, A.A. 23,734
Kulyupin, Y.A. 24,340
Kunin, V.Y. 23,986
Kunnmann, W. 23,771
Kuno, H.J. 24,584
Kuper, C.G. 24,007
Kura, I. 24,000
Kurasawa, Y. 23,899
Kurono, H. 23,999
Kushida, T. 24,622
Kusmiss, J.H. 23,848
Kuti, G. 24,006
Kutnzov, V.A.G. 24,545
Kutukow, L.V. 24,794
Kuvshinskii, R.V. 24,509
Kuwahara, K. 24,192
Kuzin, N.N. 23,978

La Chapelle, T.J. 23,736
Laikhtman, B.D. 23,867
Lal, H.B. 23,891
Lam, D.J. 24,080, 24,304
Lamorte, M.F. 24,644
Lancia, F.N. 23,949
Landau, A.I. 23,671, 23,672, 23,673
Lander, J.J. 23,813
Landesman, A. 24,303
Landress, K.B. 24,599
Lang, I.G. 23,896
Larrick, R.B. 24,838
Larson, A.C. 23,592
Laskar, A.K. 23,855
Latysheva, V.M. 23,941
Laugier, J. 24,097
LaVier, E.C. 24,748
Lavrent, F.F. 23,683
Lax, B. 24,449
Leaver, K.D. 24,195
Lebed, B.M. 24,214
Lebedev, K.B. 23,516
LeBlanc, M.A.R. 24,018, 24,027
Lehman, G.W. 24,471
Lehner, L.L. 24,714
Lehovec , K. 23,775
Leibowitz, J.R. 24,541
Leipold, M. 24,492
LeMee, J. 24,591
Lems, W. 24,516
Lengye, B. 24,631
Lenhart, R.E. 24,180
Leont'yev, G.A. 23,796
Lerner, E. 24,160
Lesk, I.A. 24,689, 24,692
Leslie, D.H. 24,471
Leslie, J.D. 24,351
Lev, E.Y. 23,917
Lever, R.F. 23,787
Levina, D.A. 24,154
Levine, J.D. 23,814
Levine, M. 24,389
Levinson, L.S. 24,470
Levitt, R.S. 24,627
Levy, P.W. 23,645
Lewin, G.F. 24,638
Lewis, D.W. 24,395
Lewis, H.R. 24,648
Lewis, R.T. 24,024
Li, J.C.M. 23,678
Lien, W.H. 24,460
Lim, J.S. 24,708
Liminga, R. 23,560
Lin, C.C. 24,077, 24,082
Lind, E.L. 23,949
Lindenfeld, P. 24,479
Lindholm, F.A. 24,583
Linz, A. 23,800
Lisitsa, M.P. 24,431
Litovchenko, N.M. 23,926
Little, W. 24,762
Litton, C.W. 24,393, 24,436
Litvac-Gorskaya, L.B. 24,038
Loasby, R.G. 24,466
Lockett, J. 23,725
Logan, R.A. 24,370
Loh, E. 24,442
Lopez-Alonso, R. 23,904
Lopovok, B.L. 24,220
Loretto, M.H. 23,627
Losee, D.L. 24,683
Low, G.G. 24,240
Lowde, R.D. 24,145
Lowell, J. 24,016
Luciw, W. 24,807
Ludwig, W. 23,860
Luff, B.B. 23,523
Lundergan, C.D. 24,508
Lundin, C. 23,531
L'Vova, E.Y. 23,925
Lyndon, T.J. 23,765
Lyon, D.N. 24,826
Lyubov, B.Y. 23,648
Lyutsau, V.G. 23,656

MacAvoy, T.C. 24,667
MacChesney, J.B. 24,399
Macha, M. 23,782
Machonis, A.A. 23,832
Mackintosh, A.R. 23,849
Mackintosh, I.M. 24,575
Madaiah, N. 24,489
Madan, M.P. 24,275
Madison, J.M. 24,849
Maekawa, S. 23,735
Maffitt, K.N. 23,980
Magid, L.M. 24,475, 24,506
Mahootian, N. 24,287
Maier, H.G. 23,961
Major, K.G. 24,476
Makhov, G. 24,616
Makin, M.J. 23,716
Maksakov, B.I. 24,335
Mallett, J.F. 24,145
Mallory, W. 24,364
Malogolevets, V.G. 23,929
Mal'tsen, Y.V. 23,931, 23,932
Mandel, M. 23,882
Mandel'shtam, T.S. 24,273
Mandl, V. 24,766, 24,846
Manenkov, A.A. 24,278
Mann, K.H. 23,529
Manning, R.J. 24,512
Manuilova, A.A. 24,208
Marazzi, C. 24,711
Marburger, H. 23,940
Marco, C. 23,882
Marcus, J.A. 23,852, 23,854, 24,244, 24,318
Markovskii, L.Y. 24,375
Marple, D.T.F. 24,359, 24,360, 24,444, 24,445
Marsh, J.B. 23,572
Marshall, R. 24,400
Marshall, S.A. 24,280
Martellucci, S. 24,855
Martin, A. 24,591
Martin, W.S. 24,432
Martinelli, R.U. 24,660
Maruyama, S. 23,958
Marx, G. 24,006
Maserjian, J. 23,785
Massalski, T.B. 23,715
Massey, A.G. 23,517
Masuda, Y. 24,302, 24,311
Masumoto, K. 24,323
Masuno, K. 23,900
Matcovich, T.J. 24,807
Mathews, D.R. 24,728
Mattheiss, L.F. 23,837
Mattis, D.C. 24,129
Matuura, K. 23,864
Matz, D. 23,934
Mauer, P. 24,666
Maurer, R.D. 24,667
May, C.E. 24,385
Maycock, J.N. 23,908
Mazelsky, R. 24,032
Mazzucato, E. 24,855
McCabe, C.L. 23,547
McCann, W. 24,109
McCloskey, D.J. 23,520
McClure, J.W. 23,847
McCluskey, E. 24,681
McCombe, B.D. 24,505
McCormick, H.B. 24,632
McCumber, D.E. 24,635
McFarland, G. 24,727
McFarland, V.R. 23,536
McGowan, W. 23,667
McGrath, J.T. 23,652
McGuire, T.R. 24,125, 24,127
McGurn, J.F. 23,704
McHargue, C.J. 23,711
McHugh, J.A. 24,066
McLachlan, D. 24,479
McMahon, D.H. 24,295
McMurtry, B.J. 24,610
McQuistan, R.B. 24,455
McPherson, J.W. 24,824
Means, J.A. 24,773
Medlin, W.L. 24,383
Mekhtiev, R.F. 24,420
Melik-Barkhudarov, T.K. 24,004
Melishkina, N.V. 24,065
Melngailis, I. 24,268
Mel'nik, P.V. 24,063
Memming, R. 23,930
Men, A.N. 24,153
Mendelsohn, L.I. 24,165
Mendelson, S. 23,700
Mendelssohn, K. 24,016
Meng, H.C. 24,139, 24,211
Menting, L. 23,985
Mercier, M. 24,096
Mermin, N.D. 24,136
Merry, R. 24,631
Meshii, M. 23,629, 24,524
Methfessel, S. 24,126, 24,127
Meyer, C.S. 24,566
Meyer, R.A. 23,745
Michel, A.E. 24,626
Michel, R.E. 24,185
Middents, P. 24,247
Mikhalenkov, V.S. 24,259
Mikuriya, N. 23,677
Miles, H. 24,525
Milford, F.J. 24,312
Miller, B.S. 23,638
Miller, N.C. 23,877
Miller, R.C. 24,032, 24,049
Mills, J. 24,111
Milone, P.A. 24,815, 24,828
Milstein, F. 24,166
Min, C.K. 23,612
Mina, R.T. 23,853
Mineeva, R.M. 24,268, 24,285
Minkiewicz, V. 24,254

Mirkin, L.I. 23,661
Mironov, I.A. 24,375
Mirzabaer, M. 24,044
Mitani, S. 23,902
Mitchell, D.I. 23,838
Mitchell, R.F. 23,721
Mitra, G.B. 23,603
Mitra, S. 24,679
Mitra, S.K. 23,603
Mitra, S.S. 24,400
Mitskevich, V.V. 24,474, 24,513
Miyashita, K. 24,379
Mizushima, M. 24,169, 24,184
Mocharnyuk, G.F. 23,662
Mochniak, J. 24,074
Mohanty, G. 23,544, 23,594
Moizhes, B.Y. 24,500
Mojoni, A. 23,620
Moley, E. 24,717
Moliner, F.G. 23,622
Montalvo, R.A. 24,244
Monteith, L.K. 24,845
Moon, R.M. 24,094, 24,095
Mooradian, A. 24,391
Moore, T.W. 24,202
Morgenthaler, F.R. 24,140
Mori, T. 23,629
Morimoto, N. 23,582
Morimoto, T. 24,042
Morosin, B. 23,579
Morreale, J. 24,482
Morris, A.W.H. 23,530
Morris, D. 23,605
Morris, L.C. 24,615
Morrish, A.H. 24,170
Morrison, J.A. 24,037
Morrison, J.R. 24,176
Moruzzi, V.L. 24,469, 24,473
Moser, F. 24,338
Moskalev, V.V. 24,307
Motchane, J.L. 24,137
Motizuki, K. 23,946
Muan, A. 23,526
Mueller, R.A. 24,596
Mueller, R.K. 23,980
Mukha, L.Y. 24,214
Mulhern, Jr., J.E. 24,567
Muller, E.K. 23,610
Mullin, J.B. 23,763
Mullins, J. 24,464
Mumaw, T. 23,640
Munesue, S. 24,327
Mura, T. 23,675
Murarka, S.P. 23,748
Murasik, A. 24,096
Murray, L.A. 24,644
Murzin, V.N. 24,441
Myers, K. 24,825
Mylov, V.P. 23,554

Nadeau, J.S. 24,532
Nadgornyy, E.M. 23,655, 23,659
Nag, B. 24,774
Nagai, K. 23,766
Nagels, P. 23,987
Nagle, J.J. 24,742
Nakajima, K. 23,694, 23,697
Nakamura, A. 24,254
Nakamura, M. 23,840
Nakamura, Y. 24,518
Nakao, Y. 24,376
Nakhodkin, N.G. 24,063
Narasimhamurity, T.S. 24,446
Narath, A. 23,579, 24,142
Narud, J.A. 24,566
Nasledov, D.N. 23,923, 24,430
Nathan, M.I. 24,626, 24,627
Nathans, R. 24,099, 24,106
Nave, P.M. 24,653
Nazarewicz, W. 24,350
Nedlin, G.M. 24,496
Nedzvetskii, D.S. 24,401
Neel, L. 24,097
Neklyudova, M.V.K. 23,660
Nelson, D.F. 24,370, 24,422, 24,649, 24,662
Nelson, Jr., R.D. 23,879
Nelson, R.H. 24,203
Nelson, W.E. 23,518
Nemoto, M. 23,698
Nereson, N.G. 24,093
Nesbitt, E.A. 24,121
Neuberger, M. 23,519
Neugerbauer, C.A. 24,011
Newell, W.E. 24,696
Newnham, R.E. 23,591
Nichols, L.W. 24,652
Nicholson, R.B. 23,532
Nicholson, M.E. 23,557
Nicholson, W.J. 23,876
Nielsen, T. 24,492
Nielson, J.W. 23,804
Nieto, M.M. 23,793
Niizeki, N. 23,903, 23,912
Nikolic, P. 23,535
Nikolaev, I.N. 24,429
Nisenoff, M. 24,144
Nishimura, A. 24,192
Nishina, Y. 24,449
Niyazova, O.R. 23,617
Noakes, J.E. 24,171
Nolle, A.W. 24,293
Nomaki, K. 23,698
Nomura, M. 23,819
Norris, W.T. 24,067
Norton, J.T. 23,585
Noskova, N.I. 23,695
Notis, M.R. 23,701
Novikova, S.I. 24,491
Nowak, W.B. 23,784
Nranyan, A.A. 23,862
Nuttal, P. 23,589
Nuttall, R. 23,723

Obidin, D.I. 24,794
Ockman, N. 24,332
O'Connor, J. 23,717
Odani, Y. 24,118
Odeh, F. 24,003
Oettel, E. 23,907
Ogasahara, T. 24,028
Ogland, J.W. 24,647
O'Hara, S. 23,777, 23,802
Ohlmann, R.C. 24,397
Ohr, S.M. 23,657
Okada, R.H. 24,744
Okano, T. 23,915
Okazaki, A. 24,240
Okimura, H. 24,413
Okuda, S. 24,551, 24,552
Oliveira, L. 24,846
Oliver, D.J. 24,621
Ol'khov, O.A. 24,199
Olovsson, I. 23,560
Olsen, C.E. 24,093, 24,205
Olsen, J. 24,046
Olson, R.O. 23,953
Omel'yanovskii, E.M. 24,504
Onley, R.E. 24,820
Ono, K. 24,524
Oredson, H.N. 24,183
Orehotsky, J.L. 23,972
Oppenheim, U. 24,355
Orth, E.D. 24,165
Orton, G.W. 23,550
Orttung, W.H. 24,461
Osaka, Y. 24,537
Osantowski, J. 24,322, 24,437, 24,439
Oshida, T. 23,735
Osipov, B.D. 23,983
Ostaszewicz, E. 24,406
Otley, K.O. 24,571
Otmakhov, Y.A. 24,241
Ott, A. 24,725
Otte, H.M. 23,702
Owen, J. 24,158
Ozaki, Y. 24,192

Packer, C.M. 23,822
Pacifico, E.M. 24,693
Padden, Jr., F.J. 23,760, 23,761
Packhomov, V.I. 23,576
Pal, A.K. 24,264
Palik, E.D. 23,838
Palmer, W. 24,179
Pankove, J.I. 24,624
Panteleev, V.A. 23,733
Pantelli, R.H. 24,320
Papon, P. 24,137
Papov, A.M. 23,981
Paranjape, V.V. 23,918
Pargas, P. 24,602
Pariiskii, V.B. 23,671
Paritskii, L.G. 24,420
Pariyskiy, V.B. 23,672, 23,673
Park, Y.S. 23,602, 24,419
Parker, D.J. 24,661
Parker, S.G. 23,779
Parks, P.N. 24,400
Parsignault, D.R. 24,847
Parsons, J.R. 23,776
Parthé, E.
Partridge, J.A. 24,385
Pashinin, P.P. 24,296
Paskin, A. 23,555
Passaglia, E. 23,658
Pastine, D.J. 23,521
Patel, A.R. 23,708
Patel, C. 24,650
Patel, J.R. 23,663
Patterson, D.A. 24,345
Patterson, J.D. 23,830
Patton, C.E. III 24,194
Pauleve, J. 24,097
Pauthenet, R. 24,096, 24,097
Pavlov, L.P. 23,611
Pavlov, P.V. 23,733
Pavlov, V.A. 23,695
Pearson, R.F. 24,187
Pearson, W.B. 23,994
Pekar, S.I. 23,951
Pemsler, J.P. 23,809
Perkins, T.D. 23,817
Perry, A.J. 23,607
Peterson, R.L. 24,269
Petit-Jean, R. 24,785
Petrov, Y.I. 24,487
Petrova, L.N. 24,477
Pettai, R. 24,758
Phariseau, P. 23,856
Phelan, Jr., R.J. 24,629
Philgreen, F.A. 23,886
Phillips, C.L. 24,684
Phillips, D.C. 23,562
Phillips, J.C. 23,841
Phillips, N.E. 24,460, 24,463
Phillips, R.A. 24,404
Pidgeon, C. 24,451
Piearcey, B. 23,537
Pieragostini, F. 23,753
Pierce, C.B. 24,344
Piguzov, Y.V. 24,507
Pike, E.R. 23,763
Pilkuhn, M.H. 23,739
Pinch, H.L. 24,116
Pincus, P. 24,238
Pinto, A.A. 24,116
Pinto, J.J. 24,775
Pitsch, W. 23,552
Pitt, C.H. 23,794
Pittman, G. 24,368
Pitts, E. 23,614
Plendi, J.N. 24,400
Plotnikov, A.F. 24,409
Plumier, R. 24,245
Pocsik, G. 24,008
Poindexter, E.H. 23,574
Pollard, H.F. 24,514
Polonis, D.H. 23,818
Pol'skii, Y.E. 24,278, 24,298
Polyakov, V.P. 24,153
Pool, M. 23,531
Pooley, D. 23,641
Pop, I. 24,078
Poplawsky, R. 24,185
Popov, A.M. 24,045
Popov, Y.G. 24,430
Pops, H. 23,604
Portis, A.M. 24,254
Potapov, L.P. 23,866
Potter, R. 24,331
Potter, R.F. 24,034
Potter, W.D. 23,807
Powell, G.W. 23,726
Pracht, D.W. 24,080
Pramann, R. 24,837
Pratt, J.N. 23,530
Pretzel, F.E. 23,639
Procopio, L.W. 24,653
Prohofsky, E.W. 24,546
Prokjorov, A.M. 24,273, 24,296, 24,342
Prosen, R.J. 24,181
Priestly, M.G. 24,319
Primak, W. 24,523
Prutton, M. 24,195
Pryor, A.W. 24,844
Pucel, R.A. 24,718
Puchalska, I.B. 24,173
Pukhov, H.Y. 24,818
Purnahagen, T.G. 24,224
Purnaiya, M. 24,589
Pustovoit, V.I. 24,536

Quate, C.F. 24,549
Qui, V.V. 24,096
Quinn, J. 24,231, 24,233

Rabinovici, B. 24,800
Raffel, J.I. 24,806
Ragle, L. 24,589
Raiche, A. 23,640
Rajagopal, A.K. 24,131
Ramaswamy, V. 24,698
Randall, Jr., J.J. 23,570
Ranon, U. 24,297
Rapoport, L.P. 24,026
Rasch, W. 23,939
Rassuchin, V.A. 23,892
Rattke, R. 24,507
Ravinskii, M.A. 23,947
Ravitz, S.F. 23,703
Rayne, J.A. 24,227, 24,540
Rediker, R.H. 24,629
Redman, M.J. 23,800
Reed, B.S. 24,620
Reich, B. 24,580, 24,581
Reisfeld, R. 24,337
Reilly, M. 23,692
Reiswig, R.D. 23,542
Remeika, J.P. 24,228, 24,662
Renton, C.A. 24,800
Reudy, J.E. 24,676
Revere, A. 23,569
Revesz, A.G. 23,571
Revyakin, B.N. 23,612
Reynolds, D.C. 24,393, 24,436
Rezanov, A.I. 24,497
Rice, W. 23,728
Richards, P.L. 24,250
Ridley, R.G. 24,850
Rieger, H. 24,151
Rimai, L. 24,274
Rindner, W. 24,561, 24,568
Riney, J.S. 24,763
Risgin, O. 24,616
Risher, R. 23,609
Risley, A.S. 24,212
Ristic, V.M. 24,738
Rite, V.H. 23,637
Robbins, P.A. 24,165
Robert, M. 24,605
Roberts, C.S. 24,593
Roberts, W.T. 23,690
Robertson, W. 23,714
Robinson, L.B. 24,166
Rockmore, D.M. 23,848
Rodbell, D.S. 24,158, 24,202
Rode, V.E. 24,161
Rodriguez, S. 24,231
Roess, D. 24,672
Rogers, C.B. 24,533
Rogers, L.A. 24,380
Roof, Jr., R.B. 23,592
Ropp, R.C. 24,394
Rosa, C.J. 23,808
Rose, K.M. 23,566
Rosen, C. 23,898
Rosenberg, A.J. 23,535
Rosengreen, A. 23,518
Rosenblyum, E.A. 24,241
Rosenthal, J.A. 24,757
Roshon, Jr., D.D. 23,568
Roth, H. 24,567, 24,568
Roth, L.M. 24,005
Roth, R.S. 23,595, 23,597
Röttgers, H.T. 24,707
Roult, G. 24,096
Rovinskiy, B.M. 23,656
Rowe, G.H. 24,468
Rowland, T.J. 24,305
Roy, S. 24,695

Royce, B.S.H. 23,62[illegible] 23,643, 23,990
Rozman, R. 24,[illegible]
Rubinshtein, B.E. 24,[illegible]
Rud'ko, S.N. 24,[illegible]
Runnels, L.K. 24,[illegible]
Rupprecht, G. 23,85[illegible] 23,858, 24,341
Rupprecht, H. 23,[illegible]
Ruth, S.B. 24,[illegible]
Ruth, V. 23,[illegible]
Ryabinkina, L.I. 24,[illegible]
Ryskin, A.I. 24,[illegible]
Ryvkin, S.M. 24,[illegible]
Ryzhova, T.V. 24,[illegible]

Saba, W. 23,[illegible]
Sack, E.A. 24,[illegible]
Sadler, J. 24,[illegible]
Sadowski, E.A. 23,[illegible]
Sagal, M.W. 24,[illegible]
Sagar, A. 24,[illegible]
Sah, C. 24,[illegible]
Saji, H. 24,[illegible]
Sakai, Y. 24,[illegible]
Sakurai, J. 24,518, 24,[illegible]
Salama, K. 24,[illegible]
Salter, F. 24,[illegible]
Samara, A. 23,[illegible]
Sambell, R.A.J. 24,[illegible]
Sanders, J.V. 23,[illegible]
Sandy, F. 23,[illegible]
Santoro, R.P. 23,[illegible]
Sarachik, M.P. 23,[illegible]
Sarver, J.F. 24,[illegible]
Sasak, W. 23,[illegible]
Sasakawa, T. 24,[illegible]
Sasaki, I. 24,[illegible]
Sasaki, Y. 23,[illegible]
Sass, A.R. 24,[illegible]
Sato, H. 23,558, 24,2[illegible] 24,246
Sato, N. 24,[illegible]
Sato, T. 24,[illegible]
Savage, H. 24,[illegible]
Savage, Jr., R.O. 24,[illegible]
Savchenko, M.A. 24,[illegible]
Savitskii, E.M. 24,[illegible]
Savitskiy, Y.M. 23,[illegible]
Sawada, K. 24,[illegible]
Sawamoto, K. 24,[illegible]
Sawatzky, E. 24,[illegible]
Sawyer, R.B. 24,[illegible]
Schablaske, R.V. 23,[illegible]
Schenker, H. 24,[illegible]
Schieber, M. 23,8[illegible] 24,119
Schiffer, J.P. 24,[illegible]
Schiffman, B.M. 24,[illegible]
Schlacter, M.M. 24,[illegible]
Schlichta, P. 23,[illegible]
Schlinder, A.I. 23,9[illegible] 24,113
Schmid, A.P. 24,[illegible]
Schnatterly, S. 23,[illegible]
Schneider, J. 24,[illegible]
Schneiderm, G. 23,[illegible]
Schneider, U. 24,[illegible]
Schnettler, 24,[illegible]
Schoband, O. 23,[illegible]
Schofield, B.H. 24,[illegible]
Scholz, H. 24,[illegible]
Schriempf, J.T. 24,[illegible] 24,085
Schuele, W.J. 24,[illegible] 24,261
Schultz, J. 24,[illegible]
Schultz, J.W. 24,[illegible]
Schulz-DuBois, E.O. 24,617

AUTHOR INDEX (Continued)

umann, R.W. 24,851
wartz, C.M. 23,575
wartz, R.S. 24,793
ar, G.B. 23,575
tt, A. 24,619
tt, R. 24,854
oggs, R.J. 24,849
vey, Jr., M.H. 24,224
lewicz, P.G. 24,820
lunov, Y.N. 23,986
ger, A. 24,151
all, B. 24,359, 24,360
del, G. 24,279, 24,299, 24,505
shi, S. 24,622
i, H. 24,805
cido, K. 24,057
le, J. 23,719
menikhin, A.N. 23,796
nerchan, A.A. 23,978
nitzky, I.R. 24,654
all, R.L. 23,627, 23,707
rahim, D.P. 24,805
rratosa, J. 24,352
rway, R.A. 24,280
ry, R.S. 24,112
thares, J.C. 24,224
jadrin, V.S. 23,975
nafer, M.W. 24,125
agurin, I.I. 24,565
rakhovtsova, S.I. 24,417
alimora, K.V. 23,611
altiel, D. 24,255
anabarger, M.R. 24,213, 24,122
eane, J.R. 24,289
apira, Y. 24,544
arma, J. 23,642
arma, K.C. 24,490
arpless, W. 24,606, 24,650
aw, H.J. 24,141
aw, J.E. 24,434
effield, J.C. 24,066
einkman, M.K. 23,922
ekun, L.Y. 24,298
eleg, A.U. 24,258
erwood, R.C. 24,121, 24,122, 24,167
newmon, P.G. 23,731
niga, K. 23,936
inida, D. 23,993
inozaki, S.S. 24,198, 24,246
ipley, M. 24,608
nipulo, G.P. 24,342
nirane, G. 24,098, 24,106
hishiyanu, F.S. 23,744
hklyarevskii, I.N. 24,328
hmartsev, Y.V. 24,044
hooter, D. 23,827
hortes, S.R. 23,742
htrikman, S. 24,168, 24,261
hufarov, G.I. 24,153
hukevich, A.K. 23,640
hull, C.G. 23,564
huskus, A.J. 24,294
ibilia, J.T. 24,788
ibley, W.A. 23,644
idorov, V.I. 23,965
iebel, R.D. 24,467
iegel, I. 24,286
iems, R. 23,705
ievers, A.J. III 24,251, 24,356
Simmons, C.D. 24,694
Simmons, R.O. 23,625
Simpson, H. 23,561
Simpson, J.H. 24,771
Singh, Y.D. 23,891
Sinkha, D.K. 23,892
Sirota, N.N. 24,258
Skeen, C.H. 23,816
Skripak, V.N. 24,483
Sladek, R.J. 23,976
Slawsky, Z.I. 24,670
Slezov, V.V. 24,407
Sliepcevich, C.M. 23,817
Slifkin, L. 23,667, 24,557
Slifkin, L.M. 24,848
Sloan, E.L. III 24,748
Slobodchikov, S.V. 23,923
Smallman, R.E. 23,687, 23,689, 23,690
Smeltzer, W.W. 23,808
Smirnov, A.I. 24,271
Smirnova, N.P. 23,805
Smith, A.W. 24,626
Smith, B.H. 24,826
Smith, C. 23,960
Smith, C.S. 24,515
Smith, G.F. 24,789
Smith, E. 24,529
Smith, G.W. 24,201
Smith, L.B. 23,847
Smith, P.A. 24,515
Smith, R.C. 24,655
Smith, R.J. 23,991
Smith, R.P. 23,747
Smith, S. 24,451
Smits, F.M. 24,570
Smolenskii, G.A. 24,088, 24,153
Smolin, M.D. 23,933
Smolin, R.P. 24,164
Smoluchowski, R. 23,628, 23,642, 23,990, 24,078
Sobelev, V.V. 23,920, 24,333
Soffer, B.H. 24,396, 24,669
Sokoloski, M. 23,940
Sokolova, E.B. 23,921
Sokol'skaya, I.L. 24,065
Sole, M.J. 23,757
Solomons, C. 24,458
Sonder, E. 23,644
Soohoo, R.F. 24,102
Soonpaa, H.H. 23,601
Soudack, A.C. 24,680
Soule, D.E. 23,847
Spain, R.J. 24,173
Sparkes, J.J. 24,579
Sparks, M. 23,946
Sparlin, D.M. 23,854
Sparnaay, M.J. 23,812
Spector, H.N. 24,547
Spedding, F.H. 24,351
Speight, M.V. 23,706
Speliotis, D.E. 24,176
Spence, R.D. 24,247
Spinolo, G. 24,402
Spitzer, W.G. 24,069
Sposato, F.J. 24,815, 24,828
Spreadborough, J. 23,688, 23,696
Srivastava, O.N. 23,578
Srivastava, R.S. 24,459
Stadler, H.L. 23,913
Stafsudd, O.M. 23,803
Stanchi, L. 24,705
Stanley, J.T. 23,754
Starobinets, S.S. 24,221
Startsev, V.I. 23,671, 23,683
Staten, H.S. 24,525
Stauss, G.H. 23,878
Steadman, R. 23,589
Stearns, M.B. 24,105
Steeds, J. 23,651
Steeves, E.C. 23,784
Stegmeier, H. 24,804
Steigmeier, E.F. 24,481
Stein, H.J. 23,615
Steinberg, H.A. 24,640
Steinhoff, H. 24,733
Steizer, E.L. 23,974
Stepanov, A.V. 23,659
Stepanov, V.G. 24,298
Stephens, D.R. 24,527
Stephenson, J.H. 24,687
Stern, F. 24,443
Sterzer, F. 24,676, 24,677, 24,733
Stevenson, D.A. 23,536, 23,781
Stevenson, R.W.H. 24,240
Stewart, A.T. 23,848, 23,850
Stiegler, J.O. 23,711
Stiglitz, M.R. 24,224
Stimler, M. 24,670
Stocker, T.L. 24,656, 24,663
Stockman, D. 24,364
Stockmann, F. 24,412
Stolnitz, D. 23,741
Strandberg, M.W.P. 24,249
Straub, W.D. 24,567
Straumanis, M.E. 23,606
Strauss, A.J. 23,528, 23,833
Strauss, W. 24,108
Strickler, D. 23,989
Stringfellow, M.W. 24,145
Stringfield, C.M. 24,843
Stroh, A.N. 23,669
Stromberg, T.F. 24,031
Strombotne, R.L. 24,309
Strong, H.M. 23,534
Strozyk, J.W. 24,658
Strudel, J.L. 23,680
Strukov, B.A. 24,472
Strutt, M.J.O. 24,576
Stupochenko, N.N. 24,314
Strutt, M.J.O. 24,047
Su, K.L. 24,684
Subbaras, E. 23,988
Suchkov, Y.D. 23,883
Sugano, T. 24,582
Sugita, Y. 23,819
Sugimoto, Y. 24,042
Suits, J.C. 24,100, 24,127
Sukhoparov, V.A. 24,022
Sulonen, M.S. 23,751
Summey, L.W. 24,747
Sunada, J. 23,573
Sutter, P. 23,988
Suzuki, M. 24,041
Svare, I. 24,279
Svelto, O. 24,320
Swann, P.R. 23,678
Swartz, P.S. 24,029
Swarup, P. 23,894
Sweet, M.E. 24,196
Swenson, C.A. 24,031, 24,486
Swisher, J.H. 23,547
Sylvan, T.P. 24,740
Sysoeva, L.M. 23,917
Szymaszek, J. 23,964
Sze, S.M. 24,069

Taagepera, R. 24,390
Tabor, W.J. 24,788
Tada, K. 24,582
Tagirov, V.I. 23,734
Tahir-Kheli, R.A. 24,135, 24,138
Taimuty, S. 23,898, 24,111
Tainish, R.J. 23,967
Takagi, Y. 23,890, 24,354
Takahaski, M. 24,182
Takaki, H. 24,055, 24,518
Takamura, J. 24,042
Takasu, S. 23,798
Takasugi, N. 23,999
Takei, H. 23,798
Takeya, K. 24,035
Tanaka, M. 24,210
Tanaka, S. 23,956
Tanaka, T. 23,979
Tani, B.S. 23,587
Tanner, J.M. 24,621
Tanner, L.E. 23,807
Tansel, S. 24,229
Targ, R. 24,651
Targer, B.A. 24,146
Tassinari, A.F. 24,796
Tateno, J. 24,282
Tauber, A. 24,206
Taylor, A.L. 24,266
Taylor, D.W. 24,714
Taylor, H. II 23,990
Taylor, M.T. 23,851
Taylor, R. 24,482, 24,494
Taylor, T.T. 23,874
Taylor, W.E. 23,791
Teale, R.W. 24,204
Teaney, D.T. 24,253, 24,469, 24,473
Tebble, R.S. 24,191
Tempest, W. 24,756
Terao, N. 23,590
Terhune, R.W. 24,144
Terrell, J.H. 23,846
Terry, G.C. 23,614
Theuerer, H.C. 23,769, 24,012, 24,013
Thiess, G. 24,769
Thiessen, L. 23,774
Thomas, D.G. 23,970, 24,370
Thomas, G. 23,650, 23,710, 24,699
Thomas, G.J. 24,834
Thomas, J. 23,588
Thomson, R. 23,622
Thorsen, A.C. 24,315
Thurber, W.R. 23,992
Thurston, R.N. 24,511
Tickner, A.W. 23,529
Tinkham, M. 24,251
Title, R.S. 24,290
Tittel, K.F. 24,364, 24,643, 24,674
Tittman, B. 24,021
Tokheim, R.E. 24,230
Tokhomirova, N.A. 24,408
Tolpygo, K.B. 23,863
Tomaru, K. 24,750
Tomasch, W.J. 24,020
Tombs, N.C. 23,596
Tomlinson, R.G. 24,856
Tonks, L. 24,636
Toporets, A.S. 24,433
Torada, T. 24,645
Torok, E.J. 24,183
Torrie, B.H. 24,145
Tosima, S. 24,043
Toth, L.E. 23,703
Toth, R.S. 23,558
Toutan, M. 24,785
Towers, T.D. 24,736, 24,741
Townes, C.H. 24,618
Townsend, J.R. 23,619
Toxen, M. 24,229
Toyoda, H. 24,070
Trapp, H.D. 24,304
Trauble, H. 24,151
Treves, D. 24,168, 24,261
Troup, G.J. 24,288, 24,300
Tsidil'kovskii, I.M. 24,504
Tsikin, A.N. 23,986
Tseng, R. 24,292
Tsuboi, M. 23,865
Tsuchida, T. 24,055
Tsuya, N. 24,645
Tuchkevich, V.M. 24,044
Tufte, O.N. 23,974
Tunstall, W.J. 23,651
Turberfield, K.C. 24,240
Turik, A.V. 23,910, 23,911
Tusting, W. 24,704
Tweedale, K. 24,187
Tyaagaradzhan, R. 23,660

Uchinokura, K. 23,956
Ueda, R. 23,942
Ugai, Y.A. 24,075
Ukhanov, Y.I. 23,931, 23,932
Umanskiy, Y.S. 23,661
Unvala, B.A. 23,783
Upthegrove, W.R. 23,817
Urusovskaya, A.A. 23,660
Ushio, S. 24,028
Usui, N. 24,208
Uzunoglu, V. 24,703

Vaccari, G. 24,157
Vail'eva, L.L. 23,941
Valatin, J.G. 24,015
Val'kovskaya, M.I. 23,686
Vallin, J. 24,517
Valton, M. 24,604
Van, J.G.M. 23,984
Van De Riet, E.K. 24,801
Van Der Hoeven, Jr., B.J.C. 24,465
Van Der Ziel, A. 24,588
Van Ostenburg, D.O. 24,080
Van Ryneveld, W.P. 24,156
Vanskike, L.L. 24,149
Van Vleck, J.H. 24,209
Vasil'ev, A.M. 24,301
Vasil'eva, R.P. 24,502
Vasilos, T. 23,746
Vavilov, V.S. 24,409
Vedyaer, A.V. 24,161
Vekilov, Y.K. 24,507
Velikhova, N.A. 23,797
Venables, J.A. 23,635
Vereshchagin, I.K. 24,374
Vereshchagin, L.F. 23,978
Verma, A.R. 23,578
Vernon, Jr., F.L. 24,027
Veselovskii, P.F. 23,883
Vetrovs, A. 23,800
Viljoen, P.E. 24,156
Villalaz, C. 24,576
Vinetskii, V.L. 24,417
Vinogradova, M.N. 24,500
Vinokurov, V.M. 24,298
Vintaikin, E.F. 23,866
Vlasenko, N.A. 24,431
Vogel, F.L. 24,644
Volger, J. 24,054
Von Willisen, F.K. 24,047
Vook, F.L. 24,480
Vook, R.W. 23,692
Vorob'ev, Y.V. 24,381, 24,425

Wada, M. 24,379
Wada, T. 24,746
Wada, Y. 23,887
Wagner, C.N.J. 23,691
Wagner, P.E. 24,277
Wagner, R.S. 23,768
Wagoner, N. 24,836
Wain, H.L. 24,531
Wakim, G. 24,293
Waku, S. 23,806
Waldram, J.R. 24,023
Waldron, G.W.J. 23,652
Walford, L.K. 23,541
Walker, E.J. 24,623
Walker, W.C. 24,322, 24,437
Walles, S. 24,329
Wallis, R.F. 23,636
Wallmark, J.T. 24,590
Wallwork, G.R. 23,808
Wang, F.F.Y. 24,079
Ward, R. 24,572
Waring, J.L. 23,595, 23,597
Warke, C. 24,001
Warrington, D.H. 24,197
Warter, Jr., P.J. 24,660
Washburn, J. 23,680, 23,703
Washwell, E.R. 24,371
Watanabe, N. 23,888
Watson, R.E. 23,875
Wayman, C.M. 34,795
Webb, N. 23,559
Weber, R. 24,030
Weddeling, F.K. 23,551
Wedepohl, P.T. 23,641
Weider, H.H. 23,906, 24,094
Weiner, S. 24,839
Weinstein, M. 23,790
Weiss, R. 23,593
Weiss, R.J. 24,130
Weisberg, L.R. 23,738
Weiser, K. 24,626, 24,627
Weissmann, S. 23,533
Welch, D.O. 23,702
Weldon, L.A. 24,702
Wells, W. Jr. 24,716
Wendling, J. 23,593
Wendt, H.R. 23,787
Werkman, T. 23,772

Wert, C.A. 24,554
Wertheim, G.K. 24,398
Westmacoh, K.H. 23,687
Westmore, J.B. 23,529
Wesolowski, J. 24,074
Westwood, A.R.C. 23,713
Wheatley, J.C. 24,841
Whelehan, J. 24,717
White, C.F. 24,682
White, G.K. 23,967
White, M.H. 24,703
White, V.J. 24,820
Whitmore, D.H. 24,318
Wiegand, D.A. 23,640
Wigen, P.E. 24,213, 24,215, 24,222
Wiggins, M.J. 24,585
Wilcox, W.R. 23,759
Wilder, T.C. 23,548
Will, G. 24,099
Will, P.M. 24,821
Willardson, R.K. 23,778
Williams, C.M. 24,051, 24,113
Williams, F. 24,390
Williams, H.J. 24,121, 24,122, 24,167
Williams, W.S. 24,520
Williamson, G.K. 23,653
Wilsdorf, D.K. 23,681
Wilson, D.K. 24,267
Wilson, G.V.H. 24,300
Wilson, K. 24,708
Wilson, M. 24,160
Wilson, O. 23,779
Wilson, R.L. 24,740
Winslow, D.K. 24,230
Witteman, W.J. 23,772
Wohlers, M.R. 24,611, 24,634
Wolfe, R.L. 23,664
Wolfe, W.P. 24,101
Wolga, G.J. 24,292
Wolsky, S.P. 23,827
Wong, M. 23,524
Wood, D.L. 23,718
Wood, E.A. 23,657
Wood, M.D. 24,726
Woodall, J. 24,627
Woodbury, H.H. 23,737
Woolley, J.C. 23,535
Wooster, W.A. 23,823, 23,824
Worrell, W.L. 23,527
Worthington, P.J. 24,529
Wrenn, J. 24,769
Wriedt, D.F. 23,533
Wright, L. 23,898
Wright, M. 24,827
Wuensch, B. 23,746
Wurst, Jr., E.C. 23,742
Wyatt, A.F.G. 24,101
Wyatt, C.L. 24,713
Yafet, Y. 24,308
Yahia, J. 23,943
Yakovlev, V.A. 24,326, 24,343
Yamanaka, C. 24,657, 24,659
Yamanaka, T. 24,657, 24,659
Yamashita, J. 23,839
Yanai, H. 24,582
Yarger, C.R. 24,077
Yariv, A. 24,641
Yarovaya, R.G. 24,328
Yasukochi, K. 24,028
Yatlinko, I.I. 24,405
Yatsenko, A.F. 24,340
Yazawa, K. 24,035
Yeh, T.H. 23,743
Yemel'yanov, V.S. 23,796
Yevstyukhin, A.I. 23,796
Yockey, H.P. 24,386
Yocom, P.N. 24,664
Yoshimatsu, M. 23,690
Yoshimori, A. 24,137
Youla, D.C. 24,686
Young, B. 24,414
Young, L. 24,838
Zachmanidis, P.J. 23,913
Zaitsera, M.P. 23,
Zajac, B.J. 24,
Zakarevicius, R.A. 24,823
Zakharov, A.M. 23,
Zanon, I. 24,
Zappa, L. 23,
Zarerova, M. 24,
Zaripov, M.M. 24,
Zavt, G.S. 23,
Zawadowski, A. 24,
Zdanuk, E.J. 23,
Zherebtsova, L.I. 23,
Ziauddin, M. 24,
Ziegler, W. 24,
Zimmerman, J.E. 23,670, 24,246
Zscherpel, R. 24,8
Zucker, J. 24,4 24,499
Zyryanov, P.S. 24,

PROCEDURES FOR SECURING REPRINTS

DISSERTATION ABSTRACTS: $2.75 per thesis on microfilm. 6½¢ per page for 8½ x 11 Xerography copy, binding included. Minimum charge $3.00. Address: University Microfilms Inc., 313 North First Street, Ann Arbor, Michigan.

PATENTS: $0.25 per copy, payable in advance to Commissioner of Patents, Washington 25, D.C. Title and Patent number must be quoted.

U.S. GOVERNMENT RESEARCH REPORTS: Prices as quoted, payable in advance to Treasurer, U.S. of America.
AD reports - Office of Technical Services, U.S. Dept. of Commerce, Washington 25, D.C.
PB reports - Superintendent of Documents, Washington 25, D.C.
Title and AD or PB number must be quoted.

Abbreviations used in ordering information when no AD or PB number is given:

BIS - British Information Service (45 Rockefeller Plaza, N.Y. 20, N.Y.)
Dep. - Depository Libraries - full-size copy available - listing of libraries given in Nuclear Science Abstracts
Dep.(mc) Depository Libraries - Microcard form
DSIR - Dept. of Scientific and Industrial Research, (Lending Library Unit, 20 Chester Terrace, London)
DTI - U.S. Atomic Energy Comm., Div. Tech. Information Extension, (P.O. Box 62, Oak Ridge, Tenn.)
GPO - Superintendent of Documents, Gov. Printing Office, Washington, D.C.
HMSO - Her Majesty's Stationery Office, London
IAEA - International Atomic Energy Agency
JCL - John Crerar Library (86 E. Randolph St., Chicago 1, Ill.)
NAS - National Academy of Sciences, National Res. Council, Washington 25, D.C.
NRC - National Research Council of Canada, Ottawa, Ontario, Canada
OTS - Office of Technical Services, Dept. of Commerce, Washington 25, D.C.
UKAEA - United Kingdom Atomic Energy Authority (11 Charles II St., London, S.W. 1)
USGS - U.S. Geological Survey, Washington 25, D.C. (no charge)

Where no ordering information is available copies of the reports may be obtained from any of the depository libraries (listed in Nuclear Science Abstracts) giving title and contract number.

LIST OF SUBJECTS COVERED BY

CAMBRIDGE COMMUNICATIONS CORPORATION'S CUMULATIVE ABSTRACTS IN BOOK FORM

For an announcement of these books see overleaf

METALLURGY

- Thermodynamics (Phase Diagrams, etc.)
- Crystal Structure
- Crystal Growth
- Crystal Processing and Environmental Effects

SOLID STATE PHYSICS

- Crystal Physics (Band Structure, etc.)
- Dielectrics
- Carrier Properties
- Conductivity
- Superconductivity
- Ferro- and Ferrimagnetism
- Paramagnetism
- Magnetoelectricity
- Optical Properties
- Thermal Properties
- Mechanical Properties

SOLID STATE DEVICES

- Diodes and Transistors
- Masers and Lasers
- Thin Films

SOLID STATE ELECTRONICS

- Amplifiers and Oscillators
- Switches and Converters
- Communications
- Instrumentation

COMPUTERS

- Logic and Switching Theory
- Digital Systems

COMPUTERS (Continued)

- Computer Hardware
- Digital Storage and Input-Output
- Computer Programming
- Mechanical Translation and Documentation
- Pattern Recognition and Artificial Intelligence
- Computer Mathematics
- Operations Research and Information Theory
- Computer Applications
- Analog and Hybrid Computers
- Real Time Systems and Automatic Control

AEROSPACE

- Electric Power in Space
- Guidance and Attitude Control
- Telecommunications
- Instrumentation (Telemetry)
- Environmental Control
- Carrier Structures
- Carrier Propulsion
- Payload Structures
- Payload Propulsion
- Unmanned Payloads
- Manned Payloads
- Manned Flight Factors
- Terrestrial Vehicles
- Lunar Vehicles
- Planetary Vehicles
- Extraterrestrial Installations
- Ground Support

ANNOUNCING...

CUMULATIVE ABSTRACTS IN BOOK FORM

A new series of 51 volumes of extraordinary value to:

METALLURGISTS,

PHYSICISTS,

ELECTRONICS ENGINEERS,

COMPUTER and AEROSPACE SPECIALISTS

Incorporating A Major Advance in the Selective Dissemination of Information

Each volume contains hundreds (in some cases thousands) of abstracts of papers and reports on a selected subject, the abstracts arranged by topic according to a detailed classification system.

The contents of each volume will be replaced annually by a new cumulative issue. In addition each volume has associated with it a supplement of current abstracts which will be replaced bimonthly by a new cumulative issue. Current awareness searches are facilitated by a separate printing of the abstracts most recently added to the current cumulative issue.

Now every scientist and engineer working in the fields covered by these books can have a continuously updated literature survey of his own specialty, right at his own desk.

For a list of subjects covered, see overleaf.

For complete descriptions and prices, write to:

CAMBRIDGE COMMUNICATIONS CORPORATION

238 MAIN STREET, CAMBRIDGE, MASSACHUSETTS, U.S.A.